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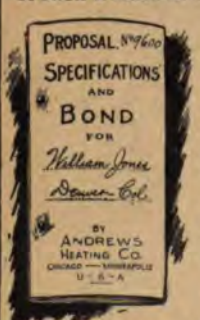

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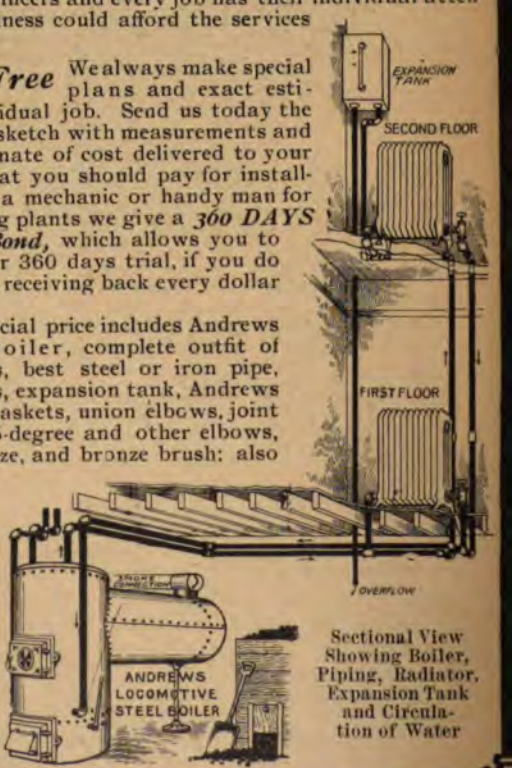

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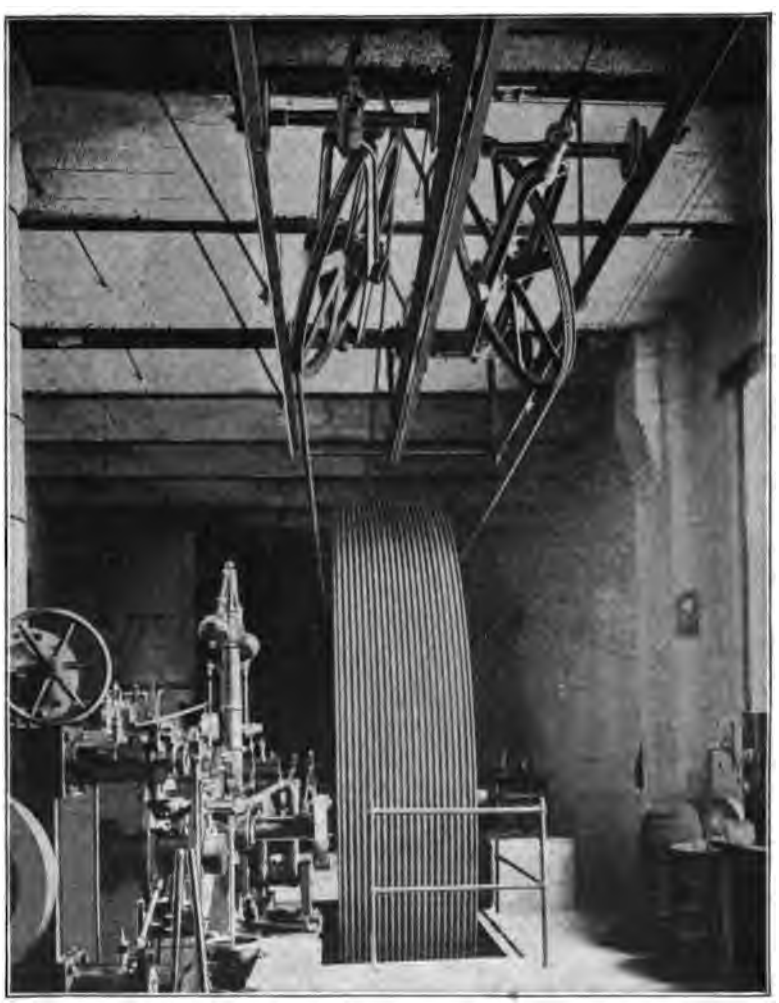

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APRIL, 1907 VOL. 15

ENGINEERING AND LIFE.

By FRANK H. CONSTANT.
Professor of Structural Engineering.

A man grows in proportion as he touches life, and no man needs this vitalizing touch more than the engineer. The world does not fully understand the engineer nor appreciate the true nobility of his work. It is inclined to regard him as uncompanionable, as unsympathetic with the higher things of life, as one with ideals which are mechanical and practical and therefore low. And, as on the one hand he has felt this lack of a humanizing bond between himself and his fellows in other walks of life, and on the other has tasted the real joy of his work and found there an absorbing interest, he has withdrawn more and more from life in its broad sense, becoming individualistic, unsocial and out of sympathy with everything not distinctly engineering in its nature. I am speaking now of the general type.

Negatively the engineer has been characterized as a man with the social instincts poorly developed, who is more at home in the field or office than in the drawing room, whose conversation runs to facts and figures rather than to general ideas and speculative truth, whose reading is confined to the almost unlimited field of technical literature with little or no browsing in the fields of letters, art, science or general knowledge, whose mental processes are concrete and mathematical and bear upon the practical problems connected with his daily work, finding little time for the vast

world of thought outside of his own calling. "I would rather have one good engineering formula than all the logic ever written," was the rather crushing reply from an engineering classmate when the writer, with doubtless much show of egotism, was displaying his newly acquired knowledge of formal logic, in the old college days. The writer remembers the loud laughter which accompanied a bright young Sibley College graduate's description of an academic classmate who was fond of scouring the country waysides with a butterfly net. Is not a general lack of sympathy with branches of knowledge whose utilitarianism is not immediately apparent, a general characteristic of the engineer? With what impatience and lack of interest most engineering students pursue prescribed studies having no immediate bearing upon their technical work. Nay more, even in a strictly technical subject the instructor must emphasize the practical bearing of each part of his instruction. Let him, in his enthusiasm, momentarily wander off by the wayside with net in hand to catch the whole truth of his subject and he is summarily brought back to the wide and beaten path by the sudden falling off of the interest of his class. How to do things, not why they are so done is the question he must satisfy.

Happily there is another, a positive side in the analysis of the engineer. Generally he is a man of sterling character, of rigid honesty in the midst of manifold temptations, devoted to his work which he finds absorbingly interesting, a hard and usually inadequately paid worker finding compensation in successful achievement, kind but firm to his subordinates, loyal to his superiors, jealous of his reputation, unostentatiously proud of his own and other engineers' achievements. Narrow, if you will, because he is little interested in letters and art, but finding his own chosen field broad enough to occupy all of his time and energy. No more narrow, therefore, than many another faithful worker who finds the business of life all absorbing. But not narrow in the sense that his intellectual development is dwarfed. for it may truthfully be said that the engineer who attains to a modicum of success must possess intellectual power and training at least equal to that required for a like degree of success in any other calling. In a word the engineer possesses character, intellectual power and an intimate acquaintance with nature's ways and laws. He needs but the humanizing touch with life to round out his character and immensely broaden his sphere of usefulness. How may he more closely touch life and how will it affect his work and personality?

The first care of a sturdy and virile man who wishes his pres-

ence in this world to add a little to the sum total of human progress, is for the partial success, at least, of his chosen life work. Now success in an engineering sense at the present day, is not simply graduation from college, a position in an office or field, and a permanent devotion to technical details which gradually narrow in scope as the advancing years bring greater and greater specialization. Such a man may rise to the head of an office, he may design important structures and justly be proud of his achievements. and yet ever wonder that his compensation is no greater. Such is the type of the older generation. The office man was out of place in the field and both office and field men were accounted impractical in the management of executive affairs. He was not supposed to have broad ideas upon economic policies nor to present what views he did have forcibly and effectively. He was selected not for executive positions but to work up the details of projects which others planned and benefited from. He was regarded as an expert technician and his success was measured by the skill he possessed in grasping technical details and his creative power in solving new and complex engineering problems. That he has risen magnificently to this height, there is no shadow of doubt. That he must be an expert technician before he can go farther is likewise true. But, in addition to this, his life and training should especially fit him to direct large business interests involving details where engineering judgment in a broad sense is the desideratum of success. His special fitness in this regard is begining to be recognized in very recent years by the business world. Just as fast as engineers have shown executive capacity they have been advanced to such positions, and generally, whenever they have taken hold, the increased efficiency of the management has been marked.

These men have developed the capacity to direct large affairs only as they have learned to understand their fellow men. Like Antaeus whose strength was renewed each time he touched mother earth, the engineer grows by contact with life which is Nature in her highest and most interesting aspect. As these words are addressed mainly to young men about to enter the profession of engineering, whose ideals for future professional success are, or should be very high, a few words of advice may not be out of place. Every piece of engineering work is ultimately performed by men, skilled or unskilled. The young engineer should endeavor from the start to learn as much as possible about these men who actually do the work. It is not enough simply to supervise their work. You cannot find the real man in such superficial contact. The important thing is to learn the workingman's

point of view, how he looks at things, his strong points, his frailties, his real capacity, his sympathies and prejudices. Such a knowledge can come only by working side by side with men. rubbing shoulder to shoulder, by being one of them. Instead of seeking a pleasant position upon an engineering staff the student should spend his vacations in the shop or on the track or in a constructor's crew. He will learn many small details in practical construction which he can get in no other way, he will get the strong body and physical vigor which are so necessary a foundation for the continuous mental strain of after years, but above all he will acquire a real knowledge of the men whom later on he must direct, organize and use efficiently. Likewise young graduates should seek the shops and field crews for their early experience. The chief engineer of a large railway system when he graduated from college, accepted an engineering position where he had to pass upon the work done by construction crews. After several years he realized that he did not really understand the work nor the men whom he had to direct. He went to a place where he was unknown and joined a railway carpentry crew; later went into a blacksmith shop; then into a foundry; finally into the mines; always starting as a novice and remaining long enough to become a master workman, foreman or superintendent. After four years of this kind of life he went back to his engineering work and advanced almost immediately into a high executive position and the knowledge of men which he gained by this experience makes him one of the leading engineers in the country. Perhaps all men will not respond equally well to this kind of experience. Many will lose sight of the end in the humble routine of elemental life, and tiring of the drudgery turn to something easier and pleasanter. Some may be harmed by the rough life. But it may be asserted that in neither case do these men have the strength of character necessary for success in the highest sense. They would have fallen by the wayside in any event. I am speaking for the men who can really succeed in engineering, who have the ambition, the character, the industry, the staying powers, the mental force. These men cannot but be helped by beginning at the bottom.

Salary and even comfort should be no consideration during the first two or three years. Call it a post graduate course if you will, what one is after is contact with men and life, full. abundant, complete. Will his ultimate advancement be delayed thereby? Probably not. In some cases it may even be hastened. Will he have forgotten much that he learned in college? Possibly. He went to college for the mental training and that still abides

with him. But he has gained a new and more vital knowledge—that of life itself—which cannot be acquired from books nor in the classroom. Moreover. if he is the right kind of a man he will not be scholastically idle during these elemental years. He will seek relief from the rough toil of the day in his books and studies. He will not be stagnating mentally but will be growing at the roots with amazing rapidity and virility. During this period, while he has been studying the real self of the men who work, he will also learn much about the men who command. As he quickly climbs from the lowest round of the ladder into higher and higher positions his interest in men will broaden and become universal. Such a man. if placed in high executive positions, will know how to meet and to move men and will understand the capacities of the men under him. Thus a constant and close touch with life is essential for his highest professional good.

Thus far we have considered success from the standpoint of professional advancement. But as man is more than vocation, so his real success in life is not to be measured wholly in terms of vocational achievement. It is in this lack of a broad appreciation of the real meaning of success that the engineer makes his greatest mistake, leading, as we have seen to the narrow type of our early characterization. Whatever broadens the whole man must necessarily better fit him for his special work. The engineer, wrapped in his individualism, imagines himself different from other men and therefore freed from their common obligations. This point of view is fallacious. Many a good physician or lawyer or minister might have became a good engineer if he had started that way, and vice versa. Doubtless the average engineer has a natural mechanical bent drawing him to mathematical and mechanical problems and in some few men this bent is so strong that they may be unsuccessful in any other calling. But few men are so decidedly called to a particular work and in most cases the final choice is a matter of great conflict of mind. Success in engineering, as in any calling, depends upon hard application and experience. The instinct to construct is native-born in most men, clearly manifested in early childhood. It is certain that the engineer is made from quite universal stuff, his growth depending upon such common elements as intellect, mental training, industry, perseverance. experience. He is above all a man and our final perspective must consider him from this view point. in which his work as an engineer must take its relative place with all the other activities of his life. It is but a part of the whole, in which all the parts are sympathetically related and all working together for the common end— the full development of the man. We can-

not therefore get this largest and truest perspective of the engineer unless we also consider him from the standpoint of his common manhood and its relation to other activities of life. He cannot develop in the highest sense as an engineer unless he likewise grows as a man.

Men are broadly classified in the two-fold way as political and social units. As a political unit the American engineer finds himself a member of a democracy. But democracy means that a grave responsibility rests upon each individual, in proportion to his capacity, to take a real part in the government of his country. President Roosevelt said in a recent address at Harvard: "I want you to feel that it is not merely your right to take part in politics. not merely your duty to the state, but that it is demanded by your own self-respect, unless you are content to acknowledge that you are unfit to govern yourself and have to submit to the rule of somebody else as master—and this is what it means if you do not do your own part in government."

The many grave problems confronting the republic will be wisely solved only when every citizen considers himself personally responsible for them and applies as much thought to their solution as he does to his private business. The responsibility of citizenship falls heavily upon the engineer, for not only is he especially fitted by his training to handle large problems, but many of the public questions involve broad engineering principles, and too often he is the most listless of citizens. If the engineer will not interest himself in these problems can he expect others to be more faithful or to find better solutions?

As a nation we are notoriously selfish in the pursuit of our own private ends, indifferent to its best welfare except when our own interests are threatened, thankful if the ship of state will but keep off of the rocks. As a democracy we have fallen far short of the ideal simply because the educated and broad sighted men of the country have not given their efforts in its behalf. The building of a bridge or railroad is undoubtedly for the public weal. But more important still is the building of the ideal democracy in which all men will truly share in its government and all problems will be solved in the spirit of unselfishness and with wisdom. Here is to be found the meaning of true patriotism—a patriotism which, day by day, in the midst of more selfish interests finds the time to work for the country's best welfare.

The engineer is likewise a member of society, from which he gets much and to which he owes much. Society is the relation of man to man. He gets from it not only the knowledge of life as it exists at present, but the history of its past development as

it has left its impress in art, literature, science and human experience. It alone has made possible the evolution of man from a lower to a higher state. In its rich soil alone the individual soul may germinate and expand into something larger and nobler. Man, and especially the engineer, cannot afford to withdraw from its stimulating influence.

We have seen how breadth of view is essential to the highest success of the engineer. So also is a broad liberal culture necessary to the development of the whole man. Truth is not confined to any one branch of human knowledge. She is like the many colored woof of cloth tracing its way in and out over the whole field. He who would know her as she truly is must seek her in many habitations. No man can compass the whole of human knowledge, but he can keep himself attune with it, ready to vibrate on all sides. I would counsel the young engineer, fixing his ideal at nothing less than the fullest development of the whole man, to let a love for knowledge—for truth as seen from many sides—spring up and grow alongside of his enthusiasm for engineering. Especially should he seek the so-called humanities, which teach of man's relation to man, for here he will find the mainspring of human action. Students of engineering should not avoid but welcome occasional subjects chosen from this group. I hope the day will come when our engineering colleges will require one or two years of academic training for entrance to the technical courses and that even these will be as broad as practicable.

A broad culture fits a man for any society. But if the end were simply selfish—his own increased enjoyment of life, or greater professional advancement—it might not be worth the seeking. But each man should pay back to society something that he takes from it, and his present duty is clear. In spite of ever increasing wealth and prosperity, in spite of great achievements in science and particularly engineering science, bringing increased comfort or luxury to every man, the ideals of society as a whole are disappointingly low. Power and wealth are sought for their own sakes; commercialism and rapid living rule the day. Nearly every one is caught in the tide and in spite of better judgment swept along with the current. It is the men of broad culture and high ideals who must lead the way to things better worth while, that the lives of the majority of men may not be wasted seeking baubles. Men may not live by bread alone. The engineer, especially, has been accused of materialistic ideals, and as one whose life is spent in a mechanical atmosphere and who often controls the spending of large sums, he is prone to over-rate the real value of these things in life. He. too, needs the broad culture

that leads to a sane perspective of life and its high ends.

Our engineering colleges draw many recruits from humble homes in which the stern conditions of life have left no place for culture. To most of these young men the engineering college is the door to a position, work that is stimulating and interesting, a comfortable living. To many this preachment may seem too idealistic and therefore impracticable. They are thankful to get a good position and to enjoy an increasing salary. They become valuable to their employers, their living is assured, they are happy. Culture (they think) is not a concomitant of engineering and having started with little why bother about it at all? The man of narrow view does not understand breadth of view; the man in the valley has no conception of what the man on the hill top is seeing. It is the men at the top and not those at the bottom (however numerous), who stamp the true character of a calling. The uncultured engineer, finding himself in a numerous crowd, may think that his view includes the whole length and breadth of engineering, and that, like a fraternal order, having once been admitted to membership he has been initiated into all its secrets and henceforth may enjoy an equal fellowship. The outside world seeing the large membership of the uncultured imagines that this is the type that all engineers must conform to—that it is essentially a narrow and unidealistic calling.

Of course this opinion is incorrect. Engineering is not a fraternal order, but a progressive vocation with a definite bottom and offering unlimited opportunities for expansion upwards. Many have reached high eminences and have enjoyed the society and friendship of the greatest men of their time. The names of great engineers have come down to us from all ages along with those of statesmen and generals. In Westminster Abbey there is a memorial tablet to Robert Stephenson, the great English bridge engineer, whilst in the crypt of the cathedral of Glasgow a similar memorial to the same man is the shrine visited by thousands. England honors many of its great engineers with knighthood. In Europe the engineering profession is regarded with honor and of equal rank with the other learned professions, but in these countries entrance into this, as into any of the professions, requires long years of very rigorous training superposed upon a broad foundation of general culture.

But it is not necessary to turn to Europe to find the true place of engineers in the society of men. This country has a long roll of honor which contains names that any profession or any country might well be proud; men who are not only great engineers, but gentlemen of the highest and broadest culture. The

young engineer should turn his eyes upward to see what engineering truly is. and in the illustratious men at the top catch the inspiration and ideal for his professional life. He will find these men truly broad both as engineers and as men, and he will find further that it is because of their breadth that they are great engineers.

Engineering is a noble calling and the men who follow it need not necessarily, if they so mind, be swallowed up in a sea of materialism. Matter is universal and clothes even the seat of thought and spirit. In molding matter to the uses of man the engineer but adapts himself to the conditions of a material world. The real engineer is the intellectual force and spirit back of matter. So far from being debased he is to be congratulated that his mind may work in such close harmony with nature. His mental process are sane and true, and drawing their inspiration from nature find there an unlimited source. He need not be ashamed of his calling; let him see to it that he is worthy of it and that he use the rich opportunity to grow into the full measure of manhood.

BALDWIN LOCOMOTIVE WORKS.

[A Sketch.]

JOHN V. MARTENIS, INSTRUCTOR IN MACHINE DESIGN, U. OF M.

Practical locomotive construction in America began in 1830. The first Baldwin locomotive was begun in 1831, so that the history of the Baldwin Locomotive Works records the progress of American locomotive engineering.

The founder, Matthias Baldwin, was a man of genius, and possessed a confidence in his abilities which is a necessary attribute to success in any line. It is also shown by his persistency in locomotive building, after his early discouragements, that he was a courageous man.

It is interesting to note the circumstances under which he came into the field of locomotive construction. He did not have the advantages of a technical education, but had learned the trade of a jeweller, which trade he followed for some years, part of the time with a firm in Philadelphia and later starting in business for himself.

Slack times compelled him to relinquish this line of work, and he then began the manufacture of book binders tools and cylinders for printing calico. This business venture proved a success and, in a short time, it became necessary for him to employ steam power to carry on his manufactures. The engine bought for this purpose proved to be unsatisfactory and occupied too much floor space, so Mr. Baldwin designed and built an engine especially adapted to his shop requirements. It was an upright, possessing many novel features, had a high efficiency, and the workmanship was excellent. This was Mr. Baldwin's first engine and procured for him many orders for others like it. This marks the transformation of a jeweller into a stationary engine builder.

It was about this time, that is in 1830, that steam locomotives began to attract the attention of American engineers. In 1800 Trevithick had made a working model, and in 1803 he constructed the first locomotive to run on iron rails. In 1829 Stephenson brought out the celebrated "Rocket," which was a success from the start.

A few locomotives had been imported from England, which

stimulated the desire to know more about them. Mr. Franklin Peale, proprietor of the Philadelphia museum, in order to gratify the public interest in the new motor, applied to Mr. Baldwin to construct a miniature locomotive for exhibition purposes. This work was undertaken and the locomotive put in motion in the museum on April 25th, 1831, on a circular track made of pine boards covered with hoop iron. The only aid Mr. Baldwin had in its construction was a number of imperfect sketches and descriptions of locomotives which had taken part in a competition in England.

The success of this model brought an order for a locomotive from the Philadelphia, Germantown and Norristown Railway Co., whose six-mile line from Philadelphia to Germantown was operated by horse power. Mr. Baldwin was guided in the construction of this locomotive by his experience on the model for the museum and by sketches and general measurements he had taken from parts of a locomotive imported for the Camden and Amboy R. R. as they lay stored in a shed but not assembled. We can scarcely appreciate at the present time the difficulties which had to be overcome in the construction of this locomotive. There were few mechanics to be had who were capable of doing this class of work and suitable tools were difficult to obtain. The cylinders were bored by a chisel fixed in a block of wood and turned by hand. Few blacksmiths were able to weld a bar of iron over 1¼" in thickness, and Mr. Baldwin was compelled to do much of the work with his own hands. He improvised tools for the various processes and educated the workmen who assisted him.

After a year of perseverence and hard labor the first locomotive was completed and christened "Old Ironsides." "Old Ironsides" was a four-wheeled engine modeled essentially on the English practice of that day, and weighed in running order something over five tons. The rear, or driving wheels, were fifty-four inches in diameter, mounted on a crank axle and placed in front of the fire box. The front wheels, which were simply carrying wheels, were forty-five inches in diameter, placed just back of the cylinders. The cylinders were nine and one-half inches in diameter by eighteen inches stroke and were attached horizontally to the smoke box, which was D-shaped, with the sides receding inwardly so as to bring the center line of each cylinder in line with the center of the crank. The wheels were made with heavy cast iron hubs, wooden spokes and rims, with wrought iron tires. The frame was of wood, placed outside of the wheels. The boiler was thirty inches in diameter and contained seventy-two copper tubes

1½" in diameter, and seven feet long. The engine had no cab. The valve motion was given by a loose eccentric for each cylinder, placed on an axle between the crank and the hub of the wheel. The engine was reversed by a lever operated from the footboard.

The road trial was made on Nov. 23d, 1832, and after remedying some minor defects, proved a marked and gratifying success.

This locomotive was at once put into service and did duty for more than a score of years.

It is related of Mr. Baldwin that his discouragements at the difficulties he had to overcome in building and procuring payment for this locomotive were such that he remarked with much decision. "This is our last locomotive." However, the subject of locomotives had become fascinating to him, and his mind was occupied in working out improvements and new ideas, so that when the next order was received some time after, he was eager to work them out in a tangible form. He was on the alert for anything by which he could improve his product, and we find in the reports that his locomotives were equal if not superior to any other make, either foreign or domestic.

The foundation of the present works was laid when, in 1835, on part of the present site, a three-story brick building was erected. Through his ingenuity and the skill of his workmen, Mr. Baldwin succeeded in increasing his output in spite of a sharp competition. Compared with the present immense plant the original one seems insignificant, and impresses one with the fact that the management has been placed in competent hands. It required thirty years to construct the first thousand locomotives while the output for the year past was 2,652, or almost nine locomotives for each working day. In the early days Mr. Baldwin employed 300 workmen; at the present time there are probably 18,000 men on the pay roll. The following figures, though not exact, give a fair idea of the magnitude of this industrial establishment:

Horse power employed, 12.000.

Floor space occupied, 37 acres.

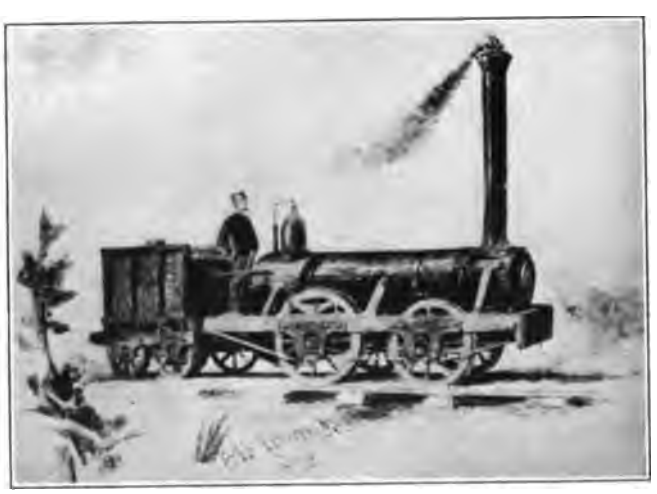
Electric motor drives, 6,000 horse power.

Electric lamps, arc and incandescent, 6,000.

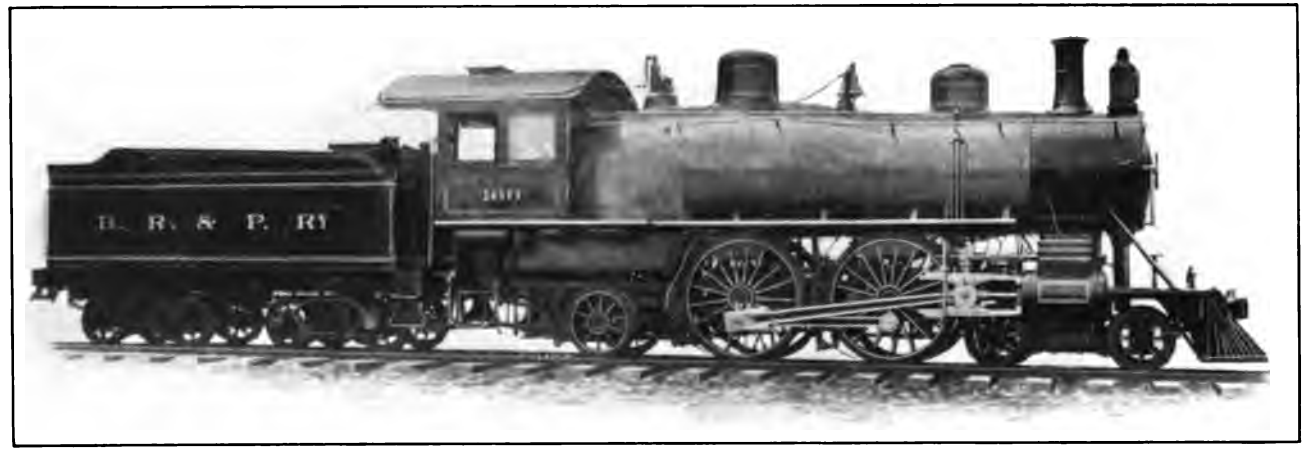
Weekly coal consumption, 2,500 tons.

Weekly consumption of material, 6,000 tons.

Before Mr. Baldwin's death in 1866, the practice of taking into the firm men of ability who had given their best efforts in the interest of the works, was begun and has been adhered to. All of the present members can recall the various steps by which they have mounted to their present enviable positions. This fact is a powerful incentive to bring out the best efforts of a young man



"OLD IRONSIDES"



A MODERN LOCOMOTIVE OF THE ATLANTIC TYPE

entering their employ. The opportunities for advancement are many and every one gets a square deal. In a busy establishment of this kind, the drone or shirker has no place, he is soon discovered, and must mend his ways if he ever expects to receive recognition. Here we encounter a significant fact, and that is, you never hear of a strike at Baldwin's; this is due largely to the generous policy there pursued.

The Baldwin system of locomotive designation is original and interesting. The letter in this system refers to the number of pairs of driving wheels. A was set aside for geared high speed locomotives; B denotes one pair of driving wheels; C two pairs; D three pairs, etc. The first number in the system shows the total number of wheels. Half of the second number plus three gives the cylinder diameter. Should there be front and rear trucks the fraction ¼ is introduced, but in case of rear truck only, 1-3 is the factor used. The last number shows the number of that class which have been constructed. To illustrate this, take the case of an Atlantic type locomotive with an eighteen inch cylinder, and we have in the Baldwin system 10-30¼-C-57. From this you note that the locomotive has ten wheels, a cylinder diameter of eighteen inches, front and rear trucks, two pairs of drivers, and it is the fifty-seventh locomotive of this class constructed. This system applied to compound locomotives shows the cylinder diameter designations, placed one above the other. Thus 10 $\frac{17}{28}$ E-32 is a compound consolidation locomotive, with 17 inch high pressure and 28 inch low pressure cylinders.

In the erecting shop, where the locomotives are assembled, we find more of interest than in any other part of the works. The first impression, upon entering the erecting shop, is one of astonishment, how it is possible to bring order out of an apparent confusion. When you understand that each workman is under the supervision of a gang foreman, and that the different classes of work are in charge of various contractors, the situation becomes clear. Moreover, the multitude of various locomotive parts which you see constantly brought in are all marked with the shop designations, and show class and number of the locomotive to which they belong. Working with this busy crowd develops an enthusiasm for the work, which cannot be understood except by the initiated. This enthusiasm is partly due to the rapid growth of a large number of various parts into a concrete unit, and each one knowing his part of the work to produce this, does it with a will. Each workman knows, also, that his efforts are sure to be rewarded in the form of an increase to the contents of his pay envelope, which he receives every Friday.

In a magazine article on "The Greatest Locomotive Works in the World," a writer makes this figurative analogy between the locomotive and the human body:

"The wheels are the legs; the frames form the backbone; the cylinders are the lungs, and the boiler, including the fire box, form the stomach of this almost human machine.

A comparison of "Old Ironsides" with the modern locomotive, shown in the illustration, indicates the improvements in American locomotive practice.

COMMERCIAL TEMPERATURE MEASUREMENTS WITH THE THERMO-ELECTRIC COUPLE.

By ANTHONY ZELENY,
Ass't Professor of Physics, University of Minnesota.

Physicists have employed the thermo-electric couple since 1812, and have shown that in many cases it is a most satisfactory method for the measurement of temperatures.

If one of the junctions of a thermo-electric couple is maintained at a constant temperature, and if the electromotive-forces are measured that are generated in the circuit when the other junction is subjected to various known temperatures, the relation between the differences in temperature and the electro-motive forces can be plotted in a curve or expressed by a mathematical equation. Any unknown temperature can then be readily determined with the aid either of the curve or of the equation.

For commercial use, the above method is too complicated and requires too great a technical training of the observer. A direct deflection method, therefore, is imperative if the thermo-electric couple is to be employed for commercial purposes. Direct reading thermo-electric pyrometers have been successfully employed for many years for the measurement of high temperatures. The scale of such an instrument is constructed by keeping one junction at the room temperature while the other one is subjected successively to various known temperatures. The points to which the index deflects are properly marked in degrees of temperature. The remainder of the scale is then completed by interpolation. The pyrometer being employed for the measurement of high temperatures only, is not sufficiently sensitive to be seriously affected by the comparatively small changes in the temperature of the room to which the reference junction is exposed. Various modifications of the above instrument are in use.

During the summer of 1901, the writer was requested to devise an accurate method for the measurement of the temperature of grain in storage, by a firm who were then constructing one of the great terminal elevators of the city and who desired to install such an instrument. This lead the writer to the development of

the thermo-electric couple for the accurate measurement of ordinary temperatures by the direct deflections method. The apparatus devised fulfills the requirement of accurately measuring the temperatures of distant or inaccessible places. It also meets the commercial requirements of durability and simplicity and of being easily understood and operated by anyone.

The various problems connected with the development are considered in succession.

1. THE METALS SELECTED FOR THE COUPLES.

The purposes for which the use of the thermo-electric couple was developed, usually require the circuits to be several hundred feet in length. It is necessary, therefore, to employ materials that are very uniform in structure, otherwise thermo-electromotive forces would be generated in different parts of the same wire. The two materials employed must also produce a large thermo-electromotive force with each other, and must not be subject to any considerable oxidation. The materials finally selected are copper and an alloy of nickel and copper. The alloy is known commercially by the letters IaIa. Sections of copper wire. taken from different parts of the same spool or from different spools, give no appreciable thermo-electromotive forces with each other. Similar sections of IaIa wire give appreciable but commercially negligible effects. Many sections, taken from the same spool at intervals of 100 feet, were tested against each other, and the maximum electromotive force that was observed would produce an effect of only 0.°1F. when the difference in the temperatures amounts to 50° F. The effect, however, is almost invariably much less than that.

2. THE THERMO-ELECTRIC POWER OF THE WIRES.

In order to construct an accurate scale for the reading of the temperatures, it was necessary to determine the relation between the differences in the temperatures of the junctions and the generated electromotive forces. One junction was maintained at O°C. by means of melting ice, while the other junction was placed in succession into the vapor of various boiling liquids and into solid carbonic acid. The temperatures were measured by means of a platinum resistance thermometer. For this purpose it was necessary to calibrate a wheatstone box bridge so that measurements with it could be made with an accuracy of 0.001%. The accuracy of the temperature measurements was tested by comparing the

value obtained for the temperature of steam with the value given from the barometric pressure. The difference in the values obtained by the two methods was only 0.°004 C.

The electromotive forces were measured by means of a Wolff potentiometer, which was tested and shown to give readings correct to within 0.01%.

The results obtained are given in Table I.

TABLE I.

1 Boiling Materials	2 Temperatures in Centigr'de Degrees	3 Measured E. M. F. $\times 10^4$	4 E. M. F. Calculated from Equat'n I	5 Difference	6 Equival't value of difference in deg. C.
Water	98.836	40.941	40.939	—.002	—0.°005
Alcohol	77.409	31.346	31.343	—.003	—0.°007
Ethyl Ether	33.455	12.891	12.907	+.016	+0.°040
Solid CO_2+Ether	—78.683	—26.520	—26.518	—.002	—0.°005

The relation between the temperature and the electromotive force was obtained by the method of least squares from the second and third columns of Table I, and the additional data, given by the fact that when both junctions are immersed in melting ice the thermo-electromotive force is zero. The computed equation is

$$0.371242\ t + 0.00043485\ t^2 = 10^4 e \qquad (I)$$

where t is the temperature of one junction in centigrade degrees, while e is the electromotive force in (U. S.) international volts when the other junction is at 0.°0C.

The fourth column of Table I gives the electromotive forces as calculated from equation (I); and a comparison of these with the observed data of the third column proves that the equation is sufficiently accurate for the purpose intended.

The first differential coefficient of equation (I) is

$$\frac{de}{dt} = \frac{0.371242 + 0.0008697t}{10^4} \qquad (II)$$

which shows that if the temperatures are plotted on the axis of abscissas and the rates at which the electromotive force changes, $\left(\frac{de}{dt}\right)$ as ordinates the resultant straight line forms with the axis of abscissas what is termed, the thermo-electric diagram of the two metals.

The point at which the two lines, if continued, would meet, is the point at which $\frac{de}{dt} = 0$.

$$\therefore \quad \frac{de}{dt} = \frac{0.371242 + 0.0008697t}{10^4} = 0$$

and

$$t = -426.°86C = -736.°35F.$$

It is not assumed that the law found to exist between —80° and +100°C. holds beyond those limits. The continuation of the lines is only an expedient by means of which, as will be shown in Sec. 3. the relative lengths of the scale divisions, within the limits of the above temperatures, can be represented graphically.

The electromotive force generated by a difference of temperature of one degree centigrade, $\left(\frac{de}{dt}\right)$, at any temperature can be calculated from equation (II) by substituting for t the value of the temperature. At 20°C., the electromotive force produced by a difference of temperature of one degree centigrade is, therefore, 0.000038864 volt.

3 THE CONSTRUCTION OF THE SCALE.[1]

Since the lines of the thermo-electric diagram are not parallel, the divisions on the scale cannot be of uniform length. Fig. 1 represents the thermo-electric diagram of the two metals. The

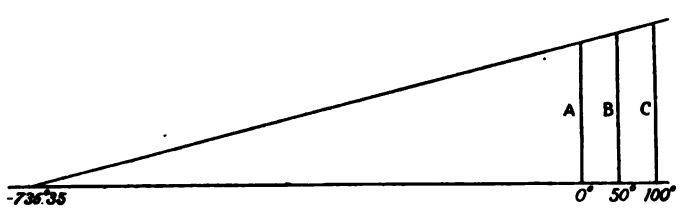


FIG. 1.

lines A, B and C represent. at different temperatures, the relative electromotive forces produced in the circuit when the difference in temperature between the two junctions is one degree. These lines, therefore, also represent the relative lengths of the degree divisions to be employed on the scale. for while representing electromotive forces, they also represent the relative currents and therefore the relative deflections when the difference in temperature between the two junctions is one degree.

If it is desired that the length of a scale division at 0° be 1

1 A. Zeleny, Galvanometer, U. S. patent, July 22, 1902; Canada patent, April 21, 1903.

millimeter, the length of a division at 100° is obtained, from Fig. 1, by means of the relation

$$A : C :: 736.35 : (736.35+100)$$

$$\text{and since } A = 1,\ C = \frac{836.35}{736.35} = 1.1358 \text{ mm.}$$

Since the divisions increase in length at a uniform rate, each degree division is, in this particular case, 0.001358 millimeter longer than the one preceding it. The magnitude of this increment changes with the length taken for the division at 0.° Fig. 2 shows a scale constructed according to this principle. It is

FIG. 2.

made on the assumption that the deflections of the galvanometer coil are proportional to the current. For precision measurements, a correction is necessary for any departure from this condition. The inverted figures of the scale are rectified when viewed through the observing telescope.

The lengths of the scale divisions can also be computed without the aid of the diagram from the relative values of $\frac{de}{dt}$ at various temperatures.

4 MOVABLE SCALE.

In commercial establishments for which this method was developed, it is very inconvenient to maintain the office or reference junction at a fixed temperature. Since the varying temperature of this junction would produce errors of similar magnitude in the readings for the temperature of the inaccessible junction, it was necessary to devise some means with which to overcome this effect. This was accomplished by the simple expedient[1] of a movable scale which, when the circuit is open,[2] is set to indicate

1 A. Zeleny, Galvanometer, U. S. and Canada patents, Loc. Cit.

2 The moving coil galvanometer often contains small thermo-electromotive forces which would produce errors of several tenths of a degree. Their effect is eliminated in the following manner: When the thermo-electric circuit is open, the switch lever is placed on a contact pin which closes another circuit of the same resistance as the first, but contains no thermo-electromotive force other than that present in the galvanometer. This thermo-electromotive force then produces the same deflection as it does when acting in the other circuit, so that when the scale is set to indicate the tempera-

the temperature of the reference junction. When the circuit is then closed, the temperature of the inaccessible junction is at once correctly indicated.

5. THE GALVANOMETER.

The galvanometers on the market, in 1901, did not fully meet all the necessary requirements. With suggestions from the writer, The Leeds and Northrup Company were able to construct a moving coil galvanometer which leaves but little to be desired. The damping is adjusted so that when the circuit for which the galvanometer is intended is closed, the motion of the coil is just aperiodic. This is of considerable importance when several hundred observations are to be taken in succession as is usually the case in practice. Readings for the temperature at different junctions can be taken at intervals of about seven seconds, while with improperly damped instruments it may require as much as several minutes. The telescope is firmly attached, so that when once properly placed, it always remains in that position. The galvanometer is screwed firmly to the wall, and there are no parts that can be accidently displaced. It remains always in adjustment and ready for use.

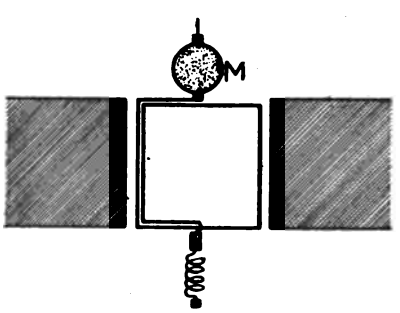


FIG. 3.

The writer wishes to emphasize the simplicity of a moving coil galvanometer. The essential active part is simply a coil of wire suspended between the poles of a magnet, as shown in Fig. 3. The only essential accessory parts are the mirror M and a telescope and scale which serve to measure the relative deflections of the coil. There are no complicated parts.

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ture of the reference junction, the same current, due to the disturbing electromotive force of the galvanometer, is acting as when the thermo-electric circuit is closed. In this manner the correction for the disturbing electromotive force is made automatically.

6. THE SIMPLICITY OF THE APPARATUS.

The simplicity of the thermo-electric circuit is illustrated in Fig. 4. Two wires of different materials soldered together to

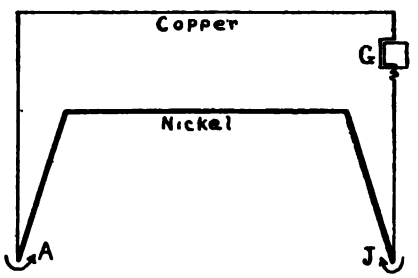


FIG. 4.

form an electric circuit and the galvanometer coil included in one of these wires, comprise all there is of the active parts of the apparatus.

The action also is explained simply, in the following manner. If two kinds of wire, for example one of copper and the other of nickel, are soldered together to form an electric circuit as shown in the figure, two junctions of dissimilar metals are formed. At each junction there exists a thermo-electromotive force whose magnitude increases with the temperature of the junction. The direction of these electromotive forces is from copper to nickel and, therefore, they are opposed to each other as indicated by the arrows in the figure. If the temperatures of the junctions A and J are equal, the electromotive forces are also equal and, being opposed, produce no current in the circuit. If the junction A is warmer than the junction J, the resultant of the two electromotive forces has the same direction as the electromotive force at A, the latter being the greater of the two. If the junction A is colder than the junction J, the current flows in the opposite direction. In either case, the amount of the current and therefore of the galvanometer deflection depends on the difference in temperature between the two junctions. With a properly constructed scale, as previously described, these deflections at once indicate the temperature of the inaccessible junction A. There are no parts that will disintegrate with time or wear out with use.

7. ADJUSTMENT OF THE APPARATUS.

An adjusting switch is employed in the circuit by means of which, when the apparatus is first installed, the resistance is made such that the deflections are of the proper size to give correct

temperature readings. The adjustment is made by setting the scale to indicate the temperature of the reference junction, while the other junction is placed in melting ice. The resistance in the circuit, when closed, is then changed by means of the adjusting switch until the galvanometer gives the correct reading for the temperature of melting ice, i. e., 32°F. The adjustment being correct for one temperature, is then correct for all temperatures.

The temperature coefficient of the galvanometer is not sufficiently large to necessitate a correction to be made for it in ordinary commercial measurements; but if a correction is desired, it is accomplished by means of a proper regulating resistance introduced into the circuit.

8 THE ZELENY THERMOMETER.[1]

The apparatus as it is actually installed is represented in Fig. 5. The single reference junction J, by means of a switch. is made to form a thermo-electric couple with any one of a multiplicity of distant junctions. This is now commercially known as "The Zeleny Thermometer."

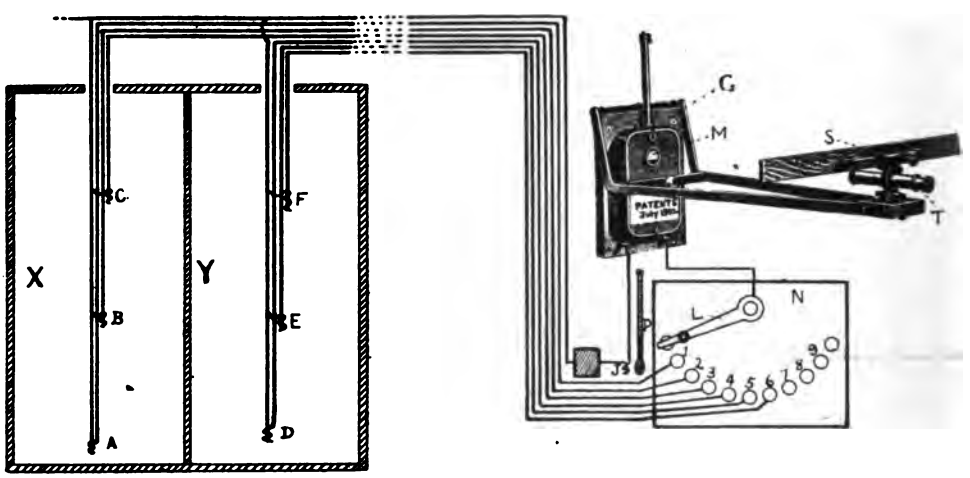


FIG. 5.

The adjusting switch is located in the common return wire as shown by the square near the reference junction J. A zero temperature coefficient wire of high resistance is permanently included causing the differences in the resistance of the different circuits, as well as the variations of the galvanometer resistance with temperature, to be negligable.

[1] A. Zeleny, Multiplex Electric Thermometer, U. S. patent, July 22, 1902; Canada patent, April 21, 1903. Electric Thermometer, U. S. patent, March 3, 1903; Canada patent, October 27, 1903.

When the lever L of the switch board is in the position shown in the figure, all the circuits are open and the scale S is moved to indicate the temperature of the office junction J as indicated by the adjacent mercury thermometer P. When the lever L is then moved to the contact pin 1, the junction A in compartment X is placed in circuit with the reference junction J and the galvanometer, forming a simple thermo-electric circuit as previously described and shown in Fig. 4. The reading on the galvanometer then gives the temperature of the point A.

When the lever is moved successively to the other contact pins shown. the galvanometer indicates in the proper order the temperatures existing at the junctions B, C, D, E and F. In this manner the temperatures of 250 distant points can be read in 30 minutes.

9. THE APPLICATION TO MEASUREMENTS OF THE TEMPERATURE OF GRAIN IN STORAGE.

The diagram of Fig. 5 represents an installation in grain storage tanks, except that the number of junctions in each tank is usually 15 instead of 3, and the switchpoard is conveniently labeled so as to indicate the tank and the position of each point within that tank. The junctions in the tanks are usually placed five feet apart.

The wires leading into the grain are enclosed in a special heavy steel conduit so as to withstand the great pull of the grain when it is being emptied. Experience has shown that this conduit must have special recessed couplings so that it cannot be bent at the threads. It must also be supported at the top and free to swing at the bottom. When the tank is empty the lower end of the conduit is tied by a small rope to the bottom of the tank so as to keep it from turning to one side when the tank is being filled. The rope breaks when the tank is being emptied, allowing the lower end of the conduit to follow the stream of grain and relieving the tension due to the horizontal component of the forces caused by the moving grain. Nothing could be made to permanently withstand the pull until the above simple facts were discovered.

In smaller tanks and in wooden bins the conduit is often attached to the sides or to the ladder and the above precautions are not required.

The wires leading from the tanks to the office are in the form of a telephone cable and the whole system is well insulated. No induced currents from neighboring transmission wires have ever been observed.

The steel conduit, enclosing the wires, conducts heat from the warmer to the colder parts. The junction within the conduit has, theoretically, a slightly different temperature than the neighboring grain, but if the temperature of the grain increases, that of the junction increases similarly. A small conduit in such a great mass of grain does not conduct the heat with sufficient rapidity to produce effects that are commercially appreciable. Repeated tests have been made and the temperature of the grain has invariably been found to be the same as that indicated by the galvanometer.

The following record illustrates what is now considered to be the proper method of keeping a record of the temperatures at various points within grain in storage. Each tank or bin has two adjacent pages reserved for it in a record book. These are sufficient for a whole season.

TANK NO. I.

1906	May 1	May 8	May 15	May 22	May 29	June 5
Office Temp. Scale set at	70	68	75	80	81	67
Feet from bottom of tank						
0	45	45	45	45	45	45
5	45	45	45	45	45	46
10	45	45	**46**	**48**	**51**	**55**
15	47	47	47	47	47	47
20	46	46	46	46	46	46
etc.	46	46	46	46	46	46

The record shows that at a point 10 feet from the bottom the grain in this tank first began to show heating on May 15, and every following observation shows an increase in temperature. When such heating occurs the elevator superintendent, at his convenience, turns the grain long before there is any danger of overheating. When grain is in good condition the temperature remains practically constant during the whole season.

10. USES.

The Thermometer has been especially devoloped, as described above, for the measurement of the temperature of grain in storage. Grain kept in store is subject to spontaneous heating and large quantities of it are often seriously injured in this manner.

The method commonly employed for preventing overheating is to frequently turn the grain. This is expensive and injurious. Frequent turning causes much of the grain to be broken; and if stored in winter and turned in summer, moisture collects on the cold grain as it comes in contact with the warmer air. It is then much more liable to heat than if it were left undisturbed.

By the use of this thermometer, the elevator superintendent always knows the condition of his grain and thereby avoids losses due to overheating and the cost and injury due to frequent unnecessary turning.

Since the Thermometer is applicable to the determination, at one convenient station, of the temperature of any number of distant points, it is useful in cold storage plants, office buildings, buildings heated from a central station, hospitals, greenhouses, mines, malting plants, breweries, coal docks, dynamo rooms, etc.

II. RELIABILITY.

This thermo-electric Thermometer gives readings as accurately as a mercury thermometer, and can be adjusted to any desired accuracy.

Each instrument is provided with at least one test junction. This is a junction similar to those that are employed for measuring the desired temperatures, except that it is accessible. Its temperature as determined by an ordinary mercury thermometer, can be compared with the reading given by the thermo-electric Thermometer. Its temperature can be varied at will. It can be placed into melting ice or under the human tongue.

The readings of these known temperatures gives a satisfactory test of the accuracy of the Thermometer. It is is desired, a further test can be made for the accuracy of any individual reading. The temperature of the office or reference junction can be varied in the same manner as was the test junction above. If the Thermometer indicates temperatures accurately, the temperature reading for the distant or inaccessible junction remains unchanged; it is independent of the temperature of the reference junction provided that at each change of temperature, the scale, when the circuit is open, is properly set to indicate the temperature of the office junction as described in Sec. 4.

These tests can be made as often as desired. There never is, therefore, any doubt as to whether the Thermometer is giving accurate indications of the unknown temperatures. This is a very important consideration.

The Thermometer has been in commercial use five years and has proved to be a reliable and a satisfactory instrument.

PORTABLE TRACTION DYNAOMETER.

Designed for use in connection with Thesis.

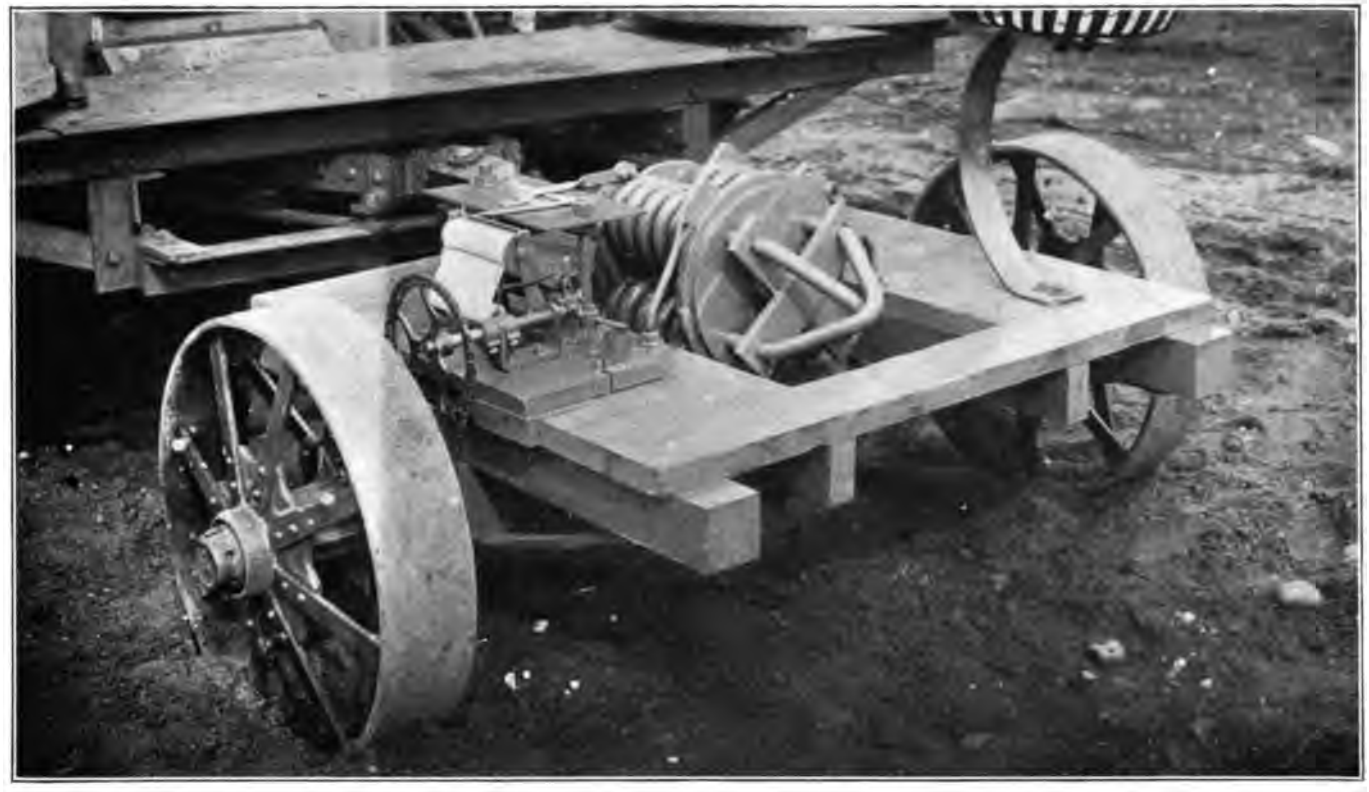
BY E. N. STACEY ('07) AND O. B. BJORGE ('07).

As a thesis, consisting of traction engine testing, would be quite incomplete without determination of tractive effort the design of this dynomometer was brought about. The design was accomplished very slowly and only after considerable experimenting, it being impossible to find any data on the subject or any information regarding the actual pull at the draw bar of a traction engine.

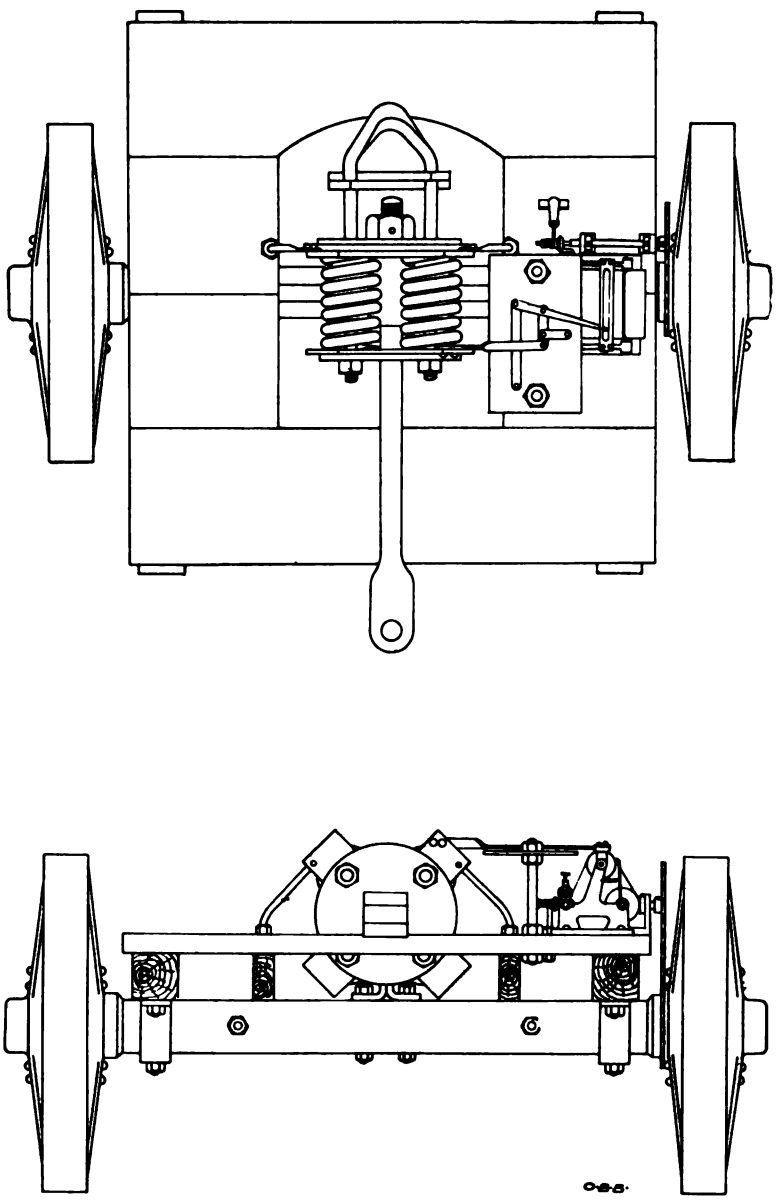
The first step in the construction of this dynamometer was the obtaining of a large spring, such as is used under railroad coaches. This one spring was carefully calibrated in the Olsen 100,000-lb. tension machine at the U. of M. laboratory. It was then arranged with a steel plate across each end, with a large bar through the middle attached to one plate. and a U bar attached to the other, With the engine fastened to the center bar, and the trailing load to the U bar. the spring was held in compression.

This little arrangement was tried, and it was found that even the smaller sized engines had no difficulty whatever in compressing the spring completely, a pull of about 10,000 lbs. being required to do this. A smaller spring was then obtained and placed inside the original one, and the same result was obtained. This smaller spring was not calibrated, but the two together probably required about 7 tons for complete compression.

When it was found that springs capable of withstanding 14,000 lbs. were inadequate, four springs were obtained. each capable of upholding about 8,000 lbs. These four springs were placed symmetrically about a central draw bar and between two end plates ½" in thickness and about 16" in diameter, with the U bar attached to one as before. Upon calibration it was found that the end plates were not of sufficient thickness to withstand pulls greater than 10 tons without considerable deflection, and these were consequently reinforced with another thickness of the same plate, the two on each end being riveted together. These reinforcing plates were made in the form of a cross, each arm of the cross to take care of one spring. This was



DYNAMOMETER DESIGNED TO MEASURE TRACTIVE EFFORT



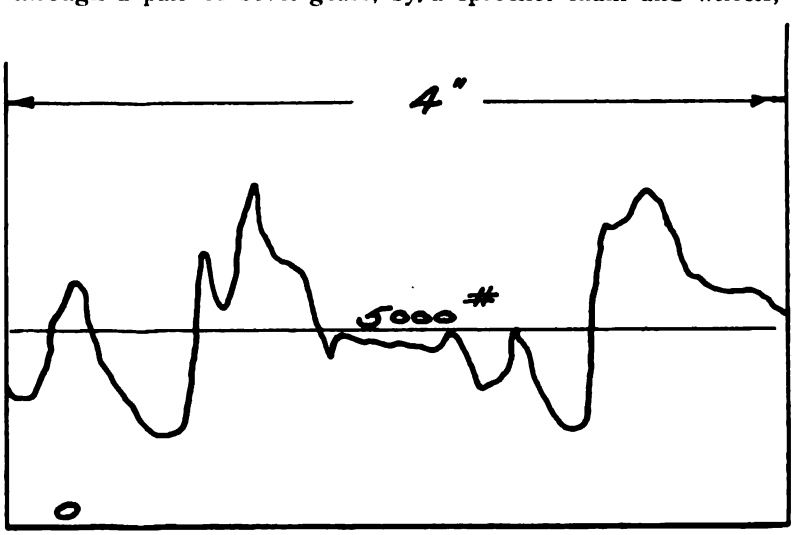
Scale Drawing of Traction Dynamometer

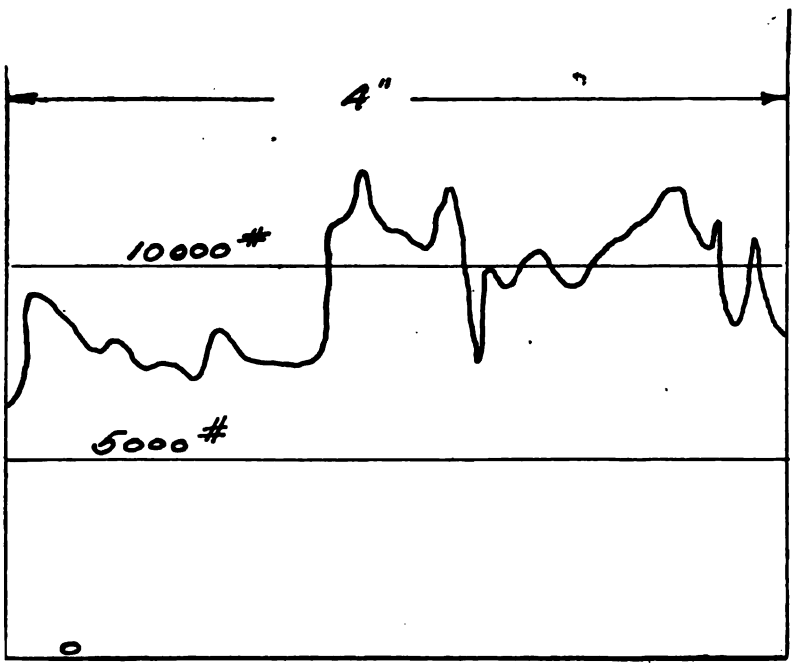
found rigid enough for the end, to which was fastened the U bar, but still too weak for the other end, where the entire pull came to the center of the plate. A circular plate ¾" in thickness and of the same diameter as the first was added to this end, riveted through the other two, and only a very slight bending was then noticeable. It was deemed advisable to insert a second U bar. in a plane at right angles to the first, thus obviating any bending of the plate that might occur after repeated trials.

This apparatus was now calibrated in the 100,000-lb. tension machine as before, and the deflection noted for each 2,000 lbs. up to 30,000 lbs. A graduated scale was attached, over which played a pointer, linked to the moving plate, so that the pull could be readily observed.

Several engines were given a chance at this combination, the smallest engine tried. registering a maximum pull of 8 tons. A 35 H. P. engine, built with the slow speed plowing gear, registered a straight horizontal pull of 26,000 lbs., or 13 tons.

From the description of this apparatus the reader can readily see that its weight became such as to make it very inconvenient to handle, and the idea naturally presented itself, of mounting it on a suitable truck, and attaching a recording mechanism, so that a continuous card could be taken. The mounting of the dynamometer on a truck is sufficiently well explained in accompanying drawing and photograph. The recording mechanism used is patterned after that used on the Flather Transmission and Absorption Dynamometer, the width being increased to allow of a six-inch roll of paper instead of a three-inch. The recorder is driven through a pair of bevel gears, by. a sprocket chain and wheels,





from the hub of one of the ground wheels. The bevel gears are so arranged that they might be thrown in and out of mesh at will, running off a card only when desirable. Thus a dynamometer card and also an indicator card from the engine, may be taken at the same time, and the two compared as to horse power and tractive effort, the speed of traveling being known. A straight line motion was interposed between the moving plate and the paper, thus giving a straight vertical motion to the pencil, with respect to the line of zero pull.

The cards shown were taken on very rough, frozen ground, which caused the extreme irregularity of the curve. It was found after repeated trials that the pencil point always returned to the correct zero mark. The springs obtained were new and were never compressed far enough to give them a permanent distortion, thus retaining their original elasticity.

These tests were conducted at the Minneapolis Threshing Machine Co.'s Works at Hopkins, Minn.

AN ELECTRICAL METHOD OF DEPOLARIZING PRIMARY BATTERIES.

FRANK W. SPRINGER.

The following article is practically a copy of a patent application made by the writer for "An Improved System for the Supply of Current Demands," with the exception that some of the non-essential descriptive details are omitted and the personal pronouns are changed from first person to the third. The patent, substantially as described below, has been recently allowed.*

The invention relates broadly to the improvement of systems for the supply of current demands, in which primary cells or batteries are employed, and has for its especial object to improve ignition systems of explosive engines. In its broad or generic phase, the invention relates not only to ignition systems, for use in connection with explosive engines or for other ignition purposes, but also relates to other apparatus such as lighting appliances. For example, it may be employed in connection with launches, and other conveyances impelled by explosive engines, and in which primary batteries are used for lighting, as well as for ignition purposes. The current demands may thus be intermittent, fluctuating, pulsating, variable or steady in character.

Primary cells or batteries are, as is well known, in extensive use in connection with ignition devices for explosive engines, and especially in connection with the so-called "jump-spark" ignition systems. Dynamos have also been extensively used in ignition systems for explosive engines.

It has been proposed to use both a primary battery and dynamo in the same ignition system, for an explosive engine, and to employ switch mechanism whereby the battery could be utilized in starting the engine, and the dynamo current could be utilized after the engine has acquired sufficient speed to cause the dynamo to generate a current of sufficient potential to produce the required spark. In such proposed arrangement, however, the actions of the primary battery and of the dynamo were independent, that

*This patent application was made through Williamson & Merchant, Minneapolis, Minnesota.

is, there was no conjoint action between the two. or otherwise stated, they were alternative devices arranged to produce the required spark at different times.

It is, of course, a well known fact that primary cells, under service, quite rapidly deteriorate and become too weak to produce the required spark producing current. This deterioration is known to be due largely to polarization caused, for example, in the case of the common "dry cell." by the collection of hydrogen on the cathode or conducting electrode of the cell. This free hydrogen, in a new "dry cell," is taken off from the electrode with considerable rapidity by chemical combination with the depolarizing agents in which the cathode is usually placed. There is always, however, even in case of a new cell, considerable loss in power of the cell due to the counter electromotive force set up by the products of electrolysis of the discharging current and to the increased resistance due to the presence of free gas, as hydrogen, on the cathode. The quantity of hydrogen deposited varies directly with the quantity of current discharged and. in the special case cited for the purpose of illustration, the amount of the depolarizing agent used in obsorbing the hydrogen varies approximately as the quantity of discharged current.

It is well known that the amount of polarization in any given primary cell depends upon the time and amount of current (amperes) flowing and the degree of exhaustion of the cell. It has also been known for some time that a polarized primary cell might be refreshed, i. e., depolarized by connecting it in a direct current circuit in such a way as to send current through it in a direction opposite to that of the usual discharging current.

In a storage battery, or reversible battery, of the lead sulphuric acid type, for example, the products of electrolysis after appearing at the electrodes during charge and discharge, are held within the cell by such chemical combination with the electrodes and electrolyte that the cell may be put through the electro chemical cycles of charge and discharge with days intervening without suffering any appreciable loss of the products of electrolysis. In primary batteries, often called "non-reversible" batteries, in general, the products of electrolysis, during discharge, escape or are absorbed or otherwise enter into non-reversible chemical combinations, after appearing at their respective electrodes, as for example, the hydrogen at the cathode (carbon electrode) and the chemical depolarizing agents of a common dry cell. If. however, each small momentary discharge, each series of discharges or a small quantity of discharge be followed by an approximately equal quantity of charging electricity, as hereinafter discussed in

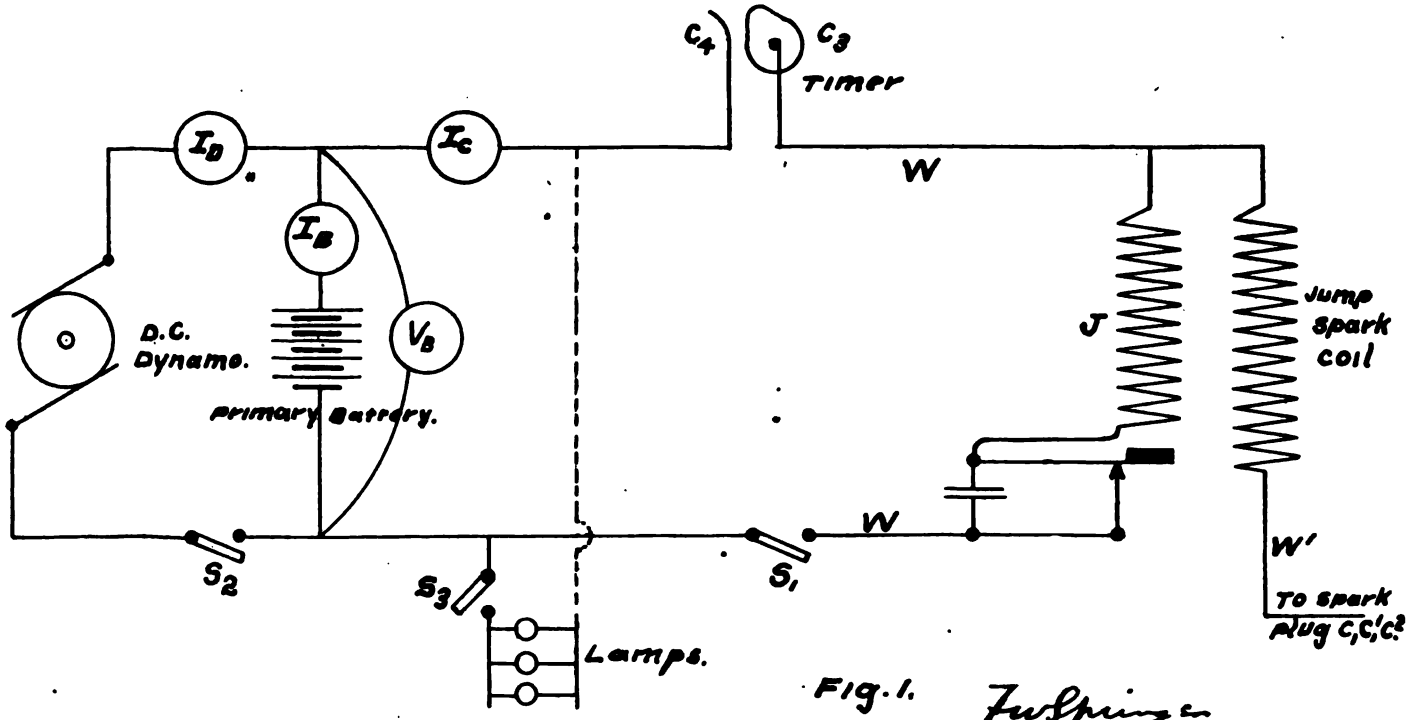


Fig. 1.

DIAGRAM OF WIRING

connection with the experiments, a large part of the products of electrolysis of discharge are caught in a nascent state before they have time to escape or enter into non-reversible chemical combinations and are put through some electro-chemical cycles, so that a primary battery, under the conditions of this invention, may be operated with approximately the same efficiency as a common storage battery, under the conditions hereinafter described.

In order to still further distinguish between primary and secondary batteries it may be stated that it is a well known fact that primary and secondary bateries are very different both in the structure and in the chemical actions that take place therein. The distinctive feature of the secondary battery is found in the fact that the chemical cycle of change is reversible, that is. a certain chemical action takes place under current discharge from the battery, and a reverse chemical action takes place under reversed current, and this is repeated again and again.*

The electro chemical actions in a primary battery, when used as a storage battery, are not the same as those of a storage battery, because the electro-chemical forms as a whole do not reappear during the successive discharges and charges of the cell. This is due, first, because some of the products of electrolysis are lost or escape during the first discharge and charge. etc.; second, some of the elements form non-reversible compounds during discharge or charge; and third, new chemical compounds are formed which are unlike or at least not entirely like the original forms. It will thus be seen that the problem of depolarizing or refreshing primary batteries and secondary batteries is not essentially the same, and because the secondary battery could be recharged in a certain manner it does not follow by analogy of reasoning that a primary battery could be recharged in the same manner.*

In case the average (chemical) current passing in and out of the primary battery is not made exactly zero, the same conditions will obtain in general and the life of the battery be prolonged or preserved. In case any demand is made upon the battery and the dynamo's supply is intermittent, fluctuating, or variable, the same general conditions of operation will also obtain.

The best results will be obtained when every momentary discharge or small quantity of discharge is followed immediately by an approximately equal quantity (coulombs) of charging current, and the smaller the time of discharge, the higher will be the efficiency. It is not necessary, however, that the time between the discharging and charging periods should always be the merest

*Inserted.

fraction of a second, as a primary battery might be used under conditions where the charge curent occurs at intervals of minutes, and not seconds, and still give fairly good results. This, however, wil depend to a large extent on the kind of primary battery used.

The above remarks apply in general to all primary batteries, although the polarizing agent is not hydrogen in all batteries.

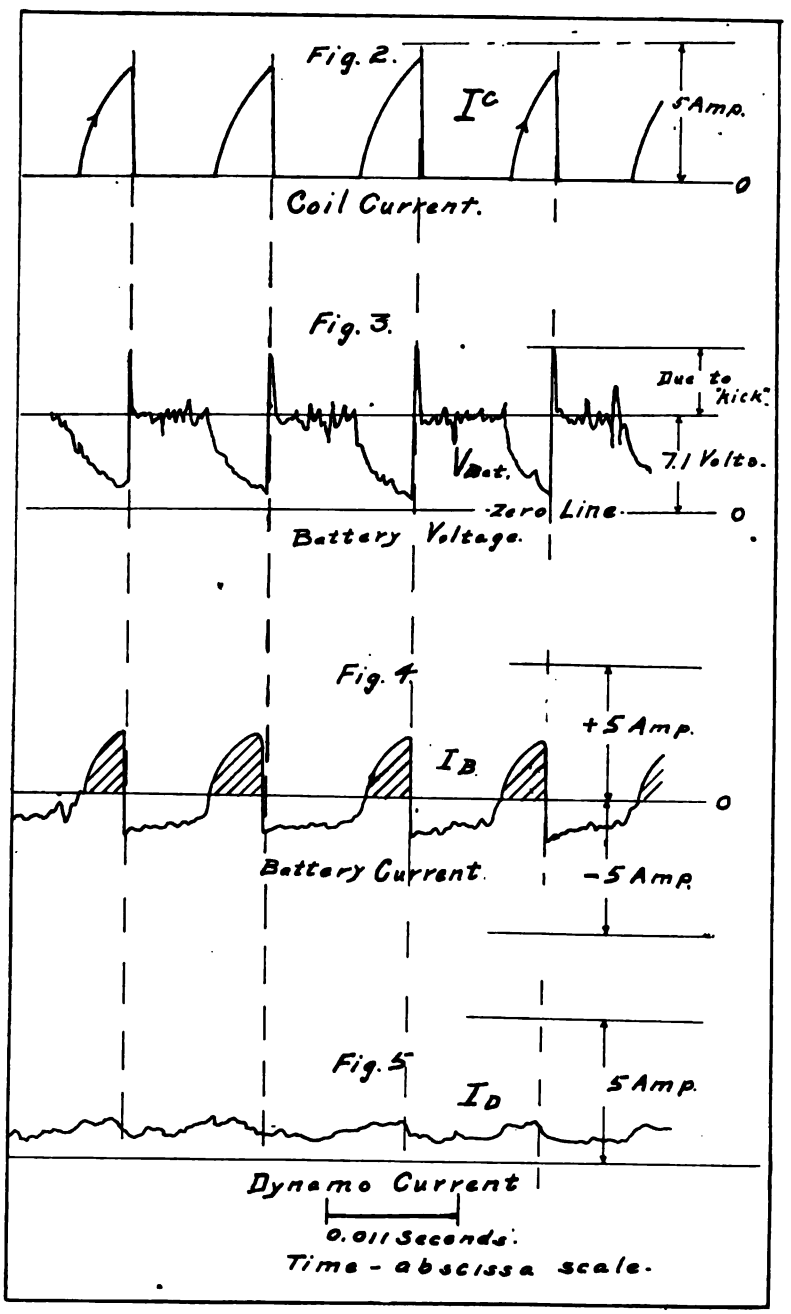
In designing this invention, the following important facts were borne in mind, to wit.: First, that if a primary batery could be depolarized to some extent, at least, following each monentary discharge or small quantity of discharge, its life would be extended very greatly, and that in any event its life would not be shortened by polarization; and furthermore, that its maximum current producing ability would be maintained and a smaller battery could be used. Second, that if a dynamo or magneto of an ignition system for explosive engines, for example, could be caused to constantly generate current and a large part of that current could be subsequently utilized to produce sparks for causing the explosion of the gas charge in the engine, at the proper times, a very much smaller dynamo could, in that event, be employed than under the present system wherein the dynamo alone is used to produce the sparks.

With the above important objects in mind. it was discovered that the above noted results, and others, could be obtained by connecting the dynamo in the primary cell or battery in multiple or parallel, and with the co-operating parts so combined and arranged that the said dynamo and primary cell or battery would act together to supply the required curent for the spark, and between sparks, or during the time intervening between the spark producing electrical discharges, the dynamo current would pass through the primary cell or battery in a direction reverse to the direction of the battery discharge current, and thereby depolarise or refresh the said cell or battery.

Experiments which have been made in practice show that with this arrangement. the hydrogen ions (cathions) which move from the anode or generating electrode to the cathode or conducting electrode in the "dry cell" cited as an example, are caught and driven backward before they have accumulated upon the electrode to such an extent as to materially reduce the power and life of the cell or battery.

One application of the invention is illustrated in the accompanying drawings, wherein:

Fig. 1 is a diagramic view, showing the improved system applied to intermittently supply current to the sparking electrodes of a single clyinder explosive engine.



OSCILLOGRAMS

Fig. 2, 3, 4 and 5 are views showing curves taken by means of an oscillograph, under the conditions hereinafter to be noted.

Fig. 2 shows the oscillograph record of the instantaneous values of the current at I_c, Fig. 3 shows a similar record of the voltage of the supply system at V. Fig 4 shows the battery current recorded by the oscillograph at I_b. and Fig. 5 shows the dynamo current record taken at I_d. While the records were being taken, the dynamo was so adjusted that the average value of the current, as measured by a permanent magnet direct current ammeter at I_b (Fig. 4) was zero. This is also indicated by Fig. 4, in which the shaded parts of the curve show the discharging currents from the batery, and the lower parts of Fig. 4, the reverse current passing into the battery from the dynamo. The average dynamo curent as indicated by Fig. 5 equals the average current taken by the coil and indicated by Fig. 2. The current passing through the battery is thus alternating in character, of comparatively high frequency, and of equal though unsymmetrical plus and minus wave forms. Such a current has a very slight permanent electro-chemical action.

It is to be noted that the curves shown in Fig. 2, 3, 4 and 5 were taken while the spark coil was in continuous operation, which would correspond to the current demand made by an eight-clyinder four-cycle engine, or a four-clyinder two (stroke) cycle engine in which the timer contacts C^3 and C^4 (Fig. 1) were made during twenty-five percent of one engine revolution for each cylinder crank shaft. All the above curves were taken with the switch S^3 open.

The first two of these five claims granted are given below:

1. The combination with a primary cell or battery, of means for intermittently sending a reverse current through said primary cell or battery, immediately following each battery discharge or series of discharges, to thereby depolarize the same.

2. The second claim is the same as the first except that the word "refresh" is substituted for "depolarize" in claim 1.

CONSTRUCTION AND MAINTENANCE OF WAY.

W. H. HOYT, CLASS '90.

Nowhere in all the field of railway construction, from its earliest date down to the present day, has there been as little actual change of design and method of construction as in that of the road-bed and track. Back in the 1820's, when the first roads were being experimented with in England and America, the first Bull head and Tee rails were set in cast iron chairs on blocks of stone about 12" to 16" square and 12" deep. In 1828, when the Baltimore and Ohio Railroad laid its first rails, their plan of permanent track was for stone blocks about 4 feet apart with Tee rails set in cast iron chairs, and they also adopted a plan of a flat strap rail laid along a stone stringer. This was intended to be their permanent construction, as it could not rot out and was supposed to be very solid. During the rush of early construction, on account of not being able to obtain stone fast enough, a makeshift was used in the form of a timber foundation. Hewed cross ties from 10" to 12" face and 8 to 10 feet long were first placed about 4 feet centers. These were notched at the points directly under the rail and a 6"x6" stringer from 12 to 40 feet in length laid lengthwise in these notches. On these stringers the strap rails were laid and spiked, then the inside corner of the timber stringer was hewed down to guide the wheel flange. Great attention was paid to the point under the bearing joint between the rail and cross-tie where the earth was excavated from 12" to 16" square and 12" deep, and the hole filled with crushed rock. This shows the early recognition of the fact that to obtain a solid track it was necessary to have a hard bearing material and good drainage. A little later when the flat rail construction was changed to a Tee rail the tie construction was also changed in that the longitudinal stringers were placed below and the cross ties. to which the Tee rail was spiked, on top. In a very early report on the construction and operation of this road, the chief engineer called the attention of the Board of Directors to the fact that the part of the road-bed which had been constructed on stone blocks with a view to being absolutely permanent, was by far the least stable of the two methods of construction, as its bearing surface was too small and it did not lend itself as readily to the lining and surfacing as the cross-tie

construction. After this the stone block construction was practically abandoned and wood construction adopted, and with the exception of a few very minor changes this is today almost unchanged and the standard construction of all railroads in the world.

In discussing the matter of Construction and Maintenance of Roadway, one of the most important features is a dry and solid road-bed under the ties, and I consider this to be the most important point in the maintenance of a good road. In any country where the average annual rainfall is over 6 inches, and this covers probably 90 per cent of the railways of the United States, it is absolutely necessary that the cross-section contour of the road-bed shall be such as to allow the water to run off rapidly and entirely. Next it is necessary to have such material for ballast as will allow the water entering it to pass rapidly through to the sub-grade, which sub-grade must be cut so as to drain the water from under the ballast if it is not porous. This shaping of the road-bed cross-section has been much discussed and permanent standard sections are now in use by nearly all railroads and these sections are designed according to the kind of ballast used and the material of the sub-grade. For good results I believe a cross-section that brings the ballast level with the top of the ties in the center, gives one inch clearance under the rail and shows from 3 to 4 inches of the tie end, will give the best results. This section to be used with gravel ballast. With crushed stone ballast the road bed can be kept a little more full, bringing the rock almost up to the top of ties at outer end. The most important point with the crushed rock ballast is to have the sub-grade so cut as to easily drain off the water that passes through the ballast. With the double track cross sections if the center between tracks is kept low it will be necessary to put in drains, either small box or dry boulder, under the tracks at distances from 400 to 600 feet to carry off the rainfall from between tracks. The sub-grade for double tracks should have its high point at the center between the tracks and should have at least a 4″ slope to the outer ditch. Taken into consideration with the question of road-bed drainage, should be the system of ditches in cuts, along the tops of cuts, and ditching along the foot of slopes to carry water to culverts and drainage ways.

Every roadbed through a clay cut should have a ditch, at least two feet below subgrade and at least seven feet wide outside of subgrade. In this country where there is so much heaving of track due to water in and under ballast, by far the best ballast that can be used is crushed granite or trap rock. This should run from

2 inches in size down to 3-4 of an inch. Such ballast placed 8 inches deep under ties with a well graded subgrade will insure a track that will not heave in winter and will not churn into holes in wet weather. The harder the rock used the better the results will be, as in ramming under the ties and working the track to line and grade, a soft rock will grind up or pulverize and will soon contain so much fine material that it will not give the track the proper drainage. Gravel ballast should run from 3 inches down to a small proportion of coarse sand and should be dressed on top to shed water easily, as it is not as porous as crushed rock and much of the rainfall will drain off the surface. There should be at least 12" of gravel under the ties and the subgrade should be cut on top to facilitate drainage, the same as that used under crushed rock.

Next to a good subgrade and well drained ballast comes an even sized. straight, sound and hardwood tie. In railway track construction, the tie question is the leading one of the hour. Where we are to get ties for the thousands of miles of track now built and to be built is a matter of great concern. In my opinion a good white oak tie is the best piece of timber ever put under a rail, but in this northern country we use almost altogether soft wood ties, such as tamarack, cedar, and nowadays even pine, spruce and balsam. The average life of a sound tamarack tie is not over 6 years under heavy main line traffic. and one or two years more in yards and sidings. A great many roads at the present time are giving their tie timber a preservative treatment to increase its life. The processes most used in this country are the Creosote, the Zinc Chloride, the Zinc Tannin and the Chloride of Mercury or Kyanizing process. Treatment with oil of Creosote is that most used in the northern section of the country while the Zinc Chloride process has been used a good deal in the southwest, where there is little rainfall. Excessive rainfall has a tendency to leach the preserving chemicals from the fiber of the timber and destroy the benefits of the treatment. Ties should be allowed to air season for several months before being placed on the track. This is absolutely necessary when treated ties are used, as it gives the wood fibre time to harden and the chemicals time to set before being placed in the ground. At the present time I am using 20 standard 8 inch face ties to the 33 foot rail length. This gives about 20 inches center to center and about 10 inches clear tamping room between ties. My experience is that this amount of timber is ample where there is a well drained crushed rock or gravel ballast, to carry safely a fifty to sixty mile per hour passenger traffic and a twenty to forty miles per hour heavy freight traffic. A great deal of use-

ful information has been obtained in late years by dating all ties used and in keeping an accurate record to ascertain the life of ties in track. In changing out ties, care should be taken to remove as nearly as possible a uniform number of ties from each rail length and these distributed its entire length. In so doing it will be much easier to maintain a track to true line and level.

One of the most important improvements that has been made in track construction in late years has been the rapidly increasing use of tie plates. With a good heavy tie plate the life of a cheap soft wood tie may be increased from thirty to fifty per cent, and at present prices of ties this will pay for the plates. Besides the increased life of ties the plates greatly strengthen the track, hold it to line and gauge and hold the rail up at joints. I consider the Improved Wolhaupter or the Q. & W.tie plates the best on the market today. For modern heavy traffic the plates should be four flanged, 3-8 inch thick, not less than 5 inches wide and at least 3 inches wider than the base of rail. This will give a rail support that will not bend down out of shape, will not split across the spike holes and can be used over and over again. Plates should have two holes on outside of rail to use two spikes, and if properly put in this should absolutely hold rails from spreading on curves. In placing tie plates on old ties, the rail should be first adzed to a good surface and all old spike holes plugged. If it is not possible to remove rails when tie plates are to be placed, the ties can be dressed off a little on each side of base of rail and the plate driven under. Plate every other tie first driving from outside toward center, setting plates well into tie and spiking up. After this plate the intermediate ties.

Next to the tie plate comes the most important part of the roadway, the rail. For modern traffic roads the rail should not be lighter than 80 lbs. to the yard. and preferably from 86 to 100 lbs. When steel rails first began to displace the soft iron rails of early construction, the steel was of a much harder composition and consequently better wearing and longer lived. As the traffic became more rapid and heavy, the weight of the rail did not keep up with it, and a great deal of trouble was experienced from rail breakage. It seemed to be the consensus of opinion of Engineers that this frequent breaking of the rail was due to its hardness and consequently the chemical composition of the metal was changed making the rail much softer. This has materially reduced the breakage but has greatly increased the cost of maintenance, due to rapid wearing out of the head of the rail. I believe if the railway companies had been willing to pay for more metal in the rail they could have reduced the breakage just as

much and saved the immense expense we are now at in constantly renewing rails. Every indication seems to me to point out that we use too light a rail and one with too soft a steel.

The proper construction of a rail joint is today as much undecided a question as it was fifteen years ago. Whether to use a suspended rail joint or a tie under the joint, whether a long or a short angle bar, whether to have four holes or six holes in the angle bars, whether to have angle bars which go under the joint or not, and dozens of other points all have their ardent advocates and often all styles of construction are found on different divisions of the same railway system. I believe the long 42" or 44" angle bar with six bolts, using joint and shoulder ties with tie plates, will give as good average results as any of the many methods, patented and otherwise, which are now on the market. The lengthening of this rail from 30 to 33 feet was a step in the right direction and it seems to me that with the standard length of cars increased to 40 feet we may eventually look for a longer standard rail. One of the hardest things to impress upon the average track man is the importance of keeping all joints fully bolted and all bolts tightly drawn up. I have found the Harvey Grip the most satisfactory bolt and have not yet seen a successful nut lock or spring nut. The only thing that will keep all nuts tight is a man and a track wrench.

On the question of bringing the track to line and grade, permanent hard wood center hubs should be set at least every 100 feet on tangents and the track lined straight from end of curve to end of curve. On curves center hubs should be every 50 feet at least, and beginning and end of curve stakes also set. All these hubs should be flush with top of tie. It is practically impossible for track men to line long stretches of tangent straight without centers. In surfacing track raise both sides up at the same time and tamp the ballast from about 12 inches of rail toward the other end. This will give the run of the tamp to outside of track and facilitate drainage. After tamping ends fill centers and dress track with good slope toward ditch. Leave ballast a little full as settlement and wash will bring it down somewhat. Especially in raising low joints should the ballast be left well cut away from the end of the tie for if the water does not get away from them, the next shower will leave them in worse shape than they were before. On roads where fast passenger traffic is maintained all curves over two degrees should have easement curves run at ends. Curve elevations should be run out to tangents on these easements.

The matter of switch and frog construction is altogether too complex to go into in a paper of this kind. Of the hundreds of

different switch points, switch stands, spring rail and rigid frogs and hundreds of patents on them it is hard to pick out the best and I do not believe the best has yet been found.

An immense amount of study and experimenting is now being done along these lines and much improvement has been made in the last few years but the field is yet wide open for improvement.

I believe the road-bed of the future will be a heavy steel rail on a reinforced concrete tie or possibly on a concrete girder with steel tie rods, but as long as changes are constantly being made in rolling stock for transporting heavier loads and making faster time. the construction of a proper road-bed is going to be an open question.

CENTRIFUGAL ELECTRIC DRIVEN FANS.

By JOHN HOWATT, CLASS '04.

A fan may be defined as a device for producing currents of air by means of rapidly revolving vanes. The air currents thus produced may be used for a variety of purposes, but only such currents as are used for the object of ventilation, together with the fans for producing them will be briefly considered in this article.

Fans for producing artificial ventilation are of two general types; one in which the general direction of the air is parallel to the axis of rotation of the fan at both inlet and outlet; the other in which air enters the fan parallel to the axis of rotation but leaves the fan in a direction at right angles to the axis. The common desk fan is a well known example of the first mentioned type. These fans are merely reversed wind mills which, as their blades are set at an angle with the shaft, catch the air at one side and force it out at the other, imparting to it a velocity proportional to the velocity of the vane.

The second type of fan is known as the centrifugal fan or blower, and is used largely where air is to be conducted along a system of piping, whether it be for the purpose of ventilation or as a carrier for light material such as sawdust and shavings. In these fans the vanes are radial, with the width of the blades set parallel to the shaft. They are surrounded by a casing which is provided with an inlet or inlets concentric with the shaft and an outlet tangential to the circle of the tips of the blades. When the fan wheel is revolved the air inside the casing is thrown outward toward the tips of the blades by centrifugal force and discharged through the outlet. This reduces the pressure of the air at the central portion of the casing below atmospheric pressure so that air flows in at the openings around the shaft to take the place of the air discharged.

These fans may be used as either blowers or exhausters. When used as blowers the casing is open on both sides around the shaft and the spaces to be ventilated receive fresh air by means of piping connected to the fan outlet. When used as exhausters the casing is closed on the motor side and the system of piping con-

nected to the other side serves to exhaust foul air from the space to be ventilated. Where natural ventilation is exceptionally poor and where poisonous gases accumulate in the air, both blower and exhaust systems may be connected to the same space.

In designing a centrifugal fan but small consideration may be given to the method by which it is to be driven. In general, for small volumes of air and high speed of rotation a fan with cast blades and a cast shell is used. This type is generally chosen also when air in which abrasive particles exist has to be moved. Fans for larger air volumes and slower speeds are made with steel plate blades and housings.

Care must be exercised in designing both the inlet and outlet to centrifugal fans lest energy be lost on account of obstructions to the free passage of air and from wasteful eddies. The air should be guided easily from the inlet to the outlet, the casing being built in the form of an arithmetical spiral, increasing toward the outlet. to accomplish this. The outlet itself can be vertical, horizontal, or at any angle whatever in a plane at right angles to the shaft, without affecting the operation of the fan.

In commercial types it is frequently found that the outlet and inlet openings provided are of the same area; under no circumstance should the area of the inlet be less than that of the outlet. Below are given the diameters of the inlet and outlet of different sizes of commercial cast shell fans. All diameters given in inches:

Diameter of wheel.	Diameter of inlet.	Diameter of outlet.
10½	6½	5¾
12	7½	7½
17½	10½	10½
20	12½	12
23	15	14½

Before attempting to lay out a system of ventilation piping or even order a fan, the general rules governing the operation of fans and the relation existing between the velocity of the fan blades, the pressure, the volume of air delivered, and the power required should be studied.

The pressure of air produced at the outlet of a centrifugal fan has been computed theoretically to be equal to that of a head of air of twice the height a body would have to fall to acquire the tangential velocity of the tips of the fan blades, or $H = \frac{v^2}{g}$. Actual experiments on fans, however, have demonstrated that the head obtainable under ordinary circumstances is but approximately half the head as calculated by the above formula so that for practical purposes, for use with fans operating at the low pressures

generally used in ventilation, the formula $H=\frac{v^2}{2g}$, or a head equal to the height a body would have to fall to acquire the velocity of the tips of the blades more nearly expresses actual conditions.

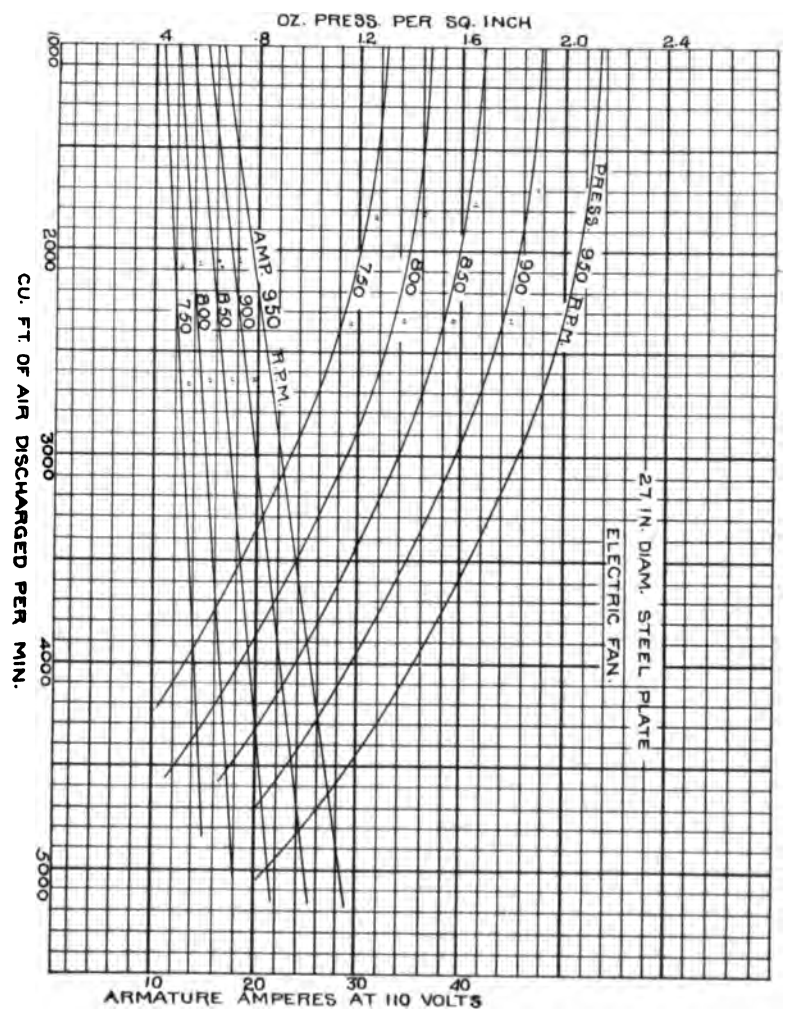
Using .08 pounds per cubic foot for the weight of pure air at 36° F. and barometric pressure of 29.9 inches of mercury the formula given above can be converted to the form, $P=\frac{v^2}{7225}$ or $v=85\sqrt{P}$ where v is the velocity of the tips of the fan blades in feet per second and P is the pressure of air at the tips of the fan blades or at the fan outlet in ounces per square inch.

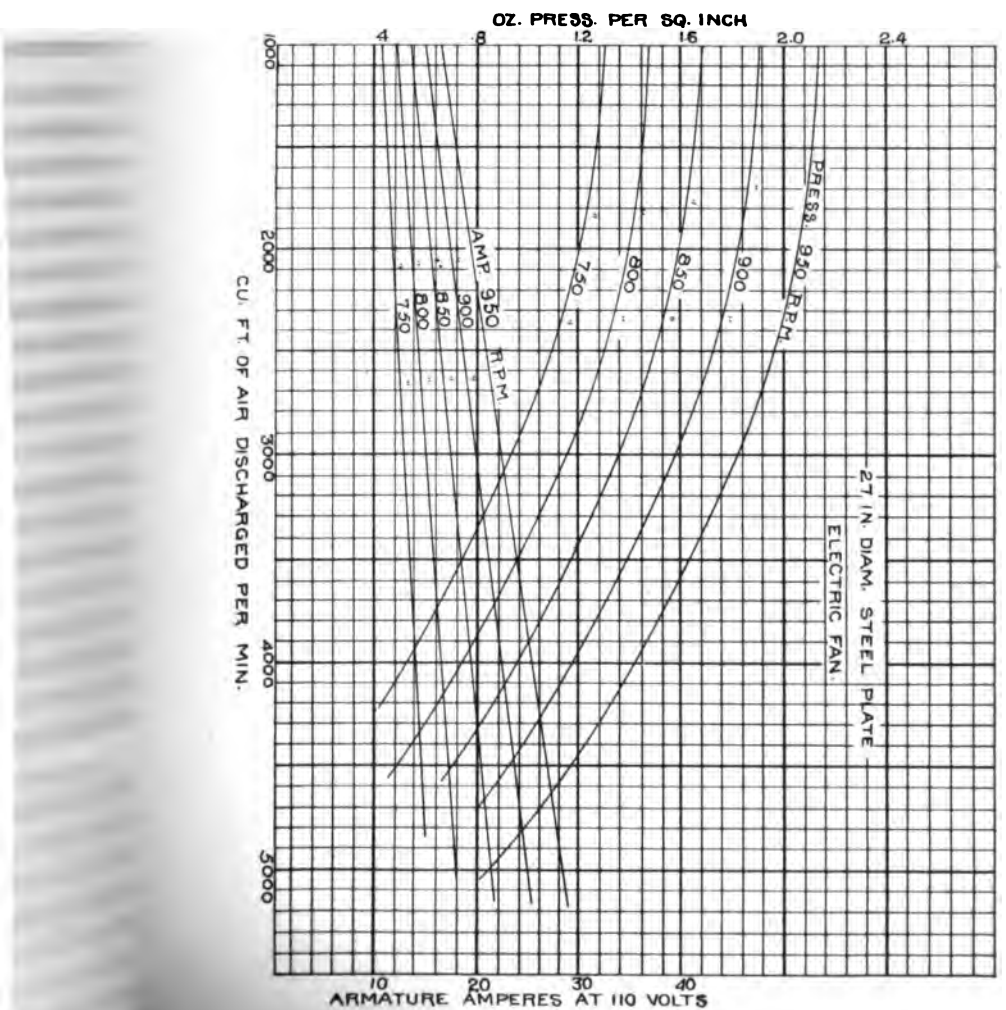
The relation existing betwen the speed, volume. pressure and power have all been worked out experimentally and may be observed by an inspection of the curves which have been plotted from results obtained on tests of centrifugal fans. It is found that the volume of air delivered by a fan increases as the square of the speed; that the pressure varies directly as the speed; and that the power required to drive a fan varies as the cube of the speed.

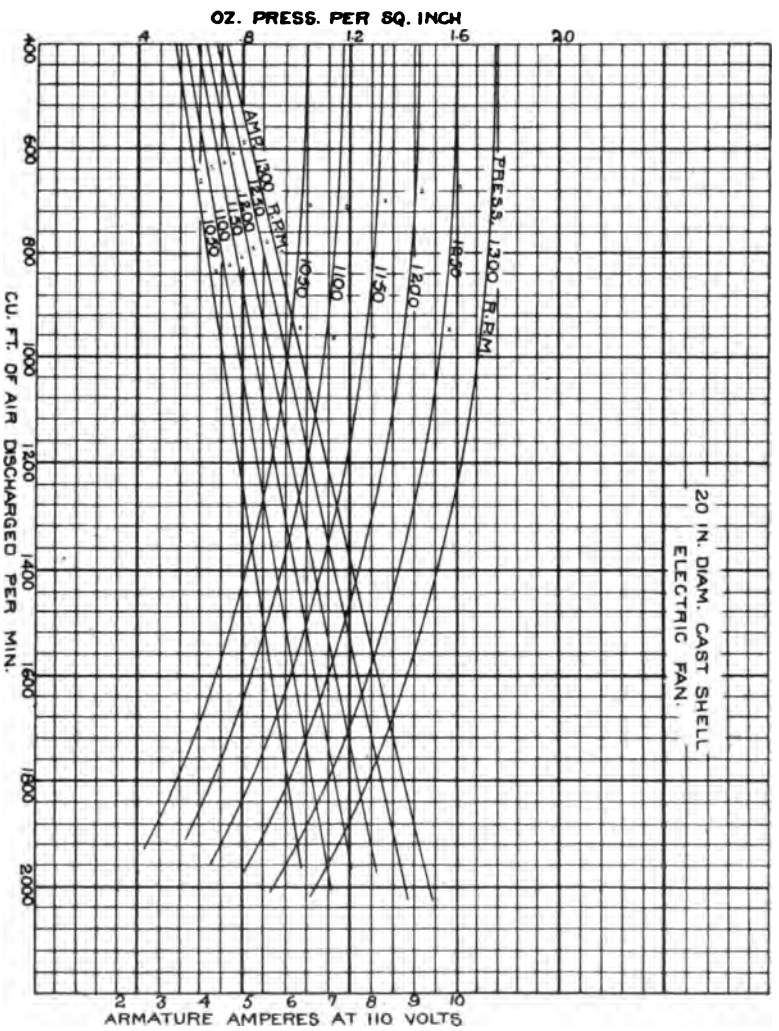
To a casual observer it would seem that, since the volume of air delivered increases as the square of the speed, a small fan running at a very high speed would be the most economical arrangement. But the power required to drive the fan would increase as the cube of the sped, or faster than the volume of air increases, so whatever would be gained in the cost of the fan would be lost in the cost of a motor of sufficient size to run the fan at the high speed. The two factors equalize each other so that a medium speed fan is the most economical arrangement where the air pressure is no consideration.

From an inspection of the curves it will be seen that the pressure of air in the outlet remains nearly constant for any given speed while the volume of air delivered is small. This is true in any centrifugal fan no matter how much air is delivered up to a point where the area of the outlet equals what is known as the capacity area or hold up area of the fan. If the area of the outlet is increased beyond this the volume of air delivered increases beyond the capacity volume of the fan, the power increases, and the pressure in the outlet decreases with the decrease in resistance. In practice the outlet area of fans greatly exceeds the capacity area so that when the dampers in the ventilation pipes are all open the air pressure is below the rated pressure.

When it has been decided what volume and pressure of air are required the size of fan and its motor equipment can be determined. When installed it frequently is found that the set is too small; that to deliver the desired quantity of air the fan has


OZ. PRESS. PER SQ. INCH
4
8
12
16
2.0
2.4
1000
2000
3000
4000
5000
AMP 950 RPM
900
850
800
750
PRESS 930 RPM
900
850
800
750
27 IN. DIAM. STEEL PLATE ELECTRIC FAN.
10
20
30
40
ARMATURE AMPERES AT 110 VOLTS
CU. FT. OF AIR DISCHARGED PER MIN.


OZ. PRESS. PER SQ. INCH
4
8
12
16
2.0
2.4
1000
2000
3000
4000
5000
CU. FT. OF AIR DISCHARGED PER MIN.
AMP 950 RPM
750
800
850
900
PRESS. 950 RPM
750
800
850
900
27 IN. DIAM. STEEL PLATE
ELECTRIC FAN.
10
20
30
40
ARMATURE AMPERES AT 110 VOLTS


OZ. PRESS. PER SQ. INCH
4
8
12
16
20
400
600
800
1000
1200
1400
1600
1800
2000
CU. FT. OF AIR DISCHARGED PER MIN.
AMP. 1300 R.P.M.
1250
1200
1150
1100
1050
1000
1050
1100
1150
1200
1250
PRESS. 1300 R.P.M.
20 IN. DIAM. CAST SHELL
ELECTRIC FAN.
2
3
4
5
6
7
8
9
10
ARMATURE AMPERES AT 110 VOLTS

to be driven at a higher speed than it was designed for with a consequent overloading of the motor. As is customary with all troubles on electrically operated equipment, the mechanical and structural part is blamed last. The real trouble, in ventilation systems such as are installed in mines and ships, is often found in the design of the piping used in distributing the air. A few simple rules observed in laying out this part of the work would often prevent the whole system from being condemned. The inside surface of all pipes should be smooth and laps at the joints made with reference to the direction of flow of air so as to offer no obstruction to its passage.

Sharp turns and bends should be avoided. A 90° bend with the inner radius of the curve not less than the diameter of the pipe causes a loss of about 10%. A bend made with a smaller radius causes a still greater loss. Branch pipes should leave the main pipe at an angle of not more than 15° and should lead from a straight length of pipe, never from the inside or outside of a curve, bending to the desired direction by easy curves. If these points are borne in mind in designing the system and sufficient allowance is made for the friction in the straight parts of the pipe no trouble should be experienced.

Where there is plenty of room, a fan may be driven by any power that is available, but where a fan has to be located in cramped quarters where it would be impossible to run a line of belting and impracticable to operate an engine, a direct connected electric motor is the most convenient arrangement. The possibility of absolutely controlling a motor from a distant point makes the electric driven fan an especially advantageous type for use in mines and tunnels. For an extensive system of ventilation the small units into which an electric driven system can be subdivided and operated is often too, a great convenience and results in a saving in loss in long transmission piping.

Shunt wound motors are nearly always used in driving ventilation fans in direct current work. The running load is a very steady one and the starting torque is negligible, being only sufficient to overcome the friction. This kind of a load permits the motor to run under very favorable conditions and its operation should be as nearly perfect as possible.

The only condition about their service, that is at all severe is that ventilation fans are often required to be run continuously for weeks at a time.

In order to get motors which will be adapted to a fan load the U. S. Government specifies the following requirements which must be met in ventilation sets purchased by it:

Motors to be shount wound and to have the highest efficiency practicable for the size and type of motor specified; All motors to be capable of operation at full load and full speed continuously for eight hours without the temperature rises exceeding the following limits:

Open Motors: Commutator 40° C; Fields 40° C;
Armature 35° C; Bearings 30° C;

Enclosed Motors: Commutator 50° C; Fields 50° C;
Armature 45° C; Bearings 30° C.

The operation at full load and full speed to be sparkless and no vibration of any of the parts permissible. A controlling panel to be supplied with every motor over ½ horse power capacity. This panel provides a speed reduction of 20% from full speed by changing the field strength; except that for motors of 1 horse power or less the speed reduction may be accomplished through armature resistance instead of field control. These requirements are most certain to insure a motor that will give satisfactory service.

A tabulated sheet of efficiencies required by the U. S. Navy is given below. While this does not give the actual fan efficiencies it gives the quantities from which they can be computed. In considering the efficiency of a ventilation set two things must be considered; the efficience of the motor; and the efficience of the fan.

Table of tests and efficiency required for electric fans with cast iron shells and curved float wheels.

Diam.	Cap		Full Outlet			Capacity Area Outlet.		
of fan	area	R. P.	vol.		Press.	vol.		Press.
in.	sq. in.	M.	cu. ft.	H. P.	oz.	cu. ft.	H. P.	oz.
		1285	296	.072	0.25	197	.055	0.50
10.5	9.17	1820	420	.206	0.50	280	.155	1.00
		2230	512	.381	0.75	342	.285	1.50
		1140	429	.105	0.25	285	.079	0.50
12	13.5	1620	608	.300	0.50	404	.225	1.00
		1980	740	.555	0.75	494	.418	1.50
		950	664	.149	0.25	403	.112	0.50
14.5	19.0	1350	867	.420	0.50	578	.315	1.00
		1650	1040	.780	0.75	695	.590	1.50
		800	833	.204	0.25	555	.153	0.50
17.5	26.3	1130	1178	.579	0.50	785	.435	1.00
		1390	1450	1.08	0.75	967	.815	1.50
		700	1052	.260	0.25	702	.195	0.50
20	33.2	994	1480	.740	0.50	987	.555	1.00
		1220	1815	1.37	0.75	1210	1.02	1.50
		595	1846	.46	0.25	1230	.350	0.50
23	58.7	842	2620	1.30	0.50	1765	.980	1.00
		1030	3235	2.40	0.75	2150	1.800	1.50
		520	2660	.650	0.25	1770	.490	0.50
26	83.3	736	3720	1.83	0.50	2488	1.38	1.00
		902	4680	3.41	0.75	3040	2.56	1.50

The motor efficiency is too well known to necessitate any explanation and may vary from 60 to 95% depending on the size of the motor. The fan efficiency is the ratio of the power delivered by the fan at its outlet, represented by the volume and pressure of air, to the power expended on the fan. This efficiency is seldom over 70% and for medium size fans is more often 65%. The fan losses occur in eddies formed at the inlet and outlet and within the casing, frictional losses, and a heat loss due to the compression of the air.

An inspection of the table will show that no consideration for the temperature and humidity of the air and for barometric pressure is made. All of these factors, however, are taken into account when the tests are made. It is frequently noticed that a fan load varies with the time of day although all dampers are kept open all the time. This is because the weight of air changes, both temperature and humidity variations influencing it. As an illustration which came under the writer's observation, a purely fan load which took 385 amperes at 120 volts during the afternoon, required 415 amperes during the early morning when the temperature was 15° F. cooler. Motors for driving fans should be large enough, however, so that factors of temperature and barometric pressure need not be considered outside of the test floor or laboratory.

Motors to be shount wound and to have the highest efficiency practicable for the size and type of motor specified; All motors to be capable of operation at full load and full speed continuously for eight hours without the temperature rises exceeding the following limits:

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A tabulated sheet of efficiencies required by t[illegible] S. Navy is given below. While this does not give the act[illegible]iencies it gives the quantities from which they can [illegible] considering the efficiency of a ventilation set tw[illegible] considered; the efficience of the motor; and the[illegible] fan.

Table of tests and efficiency [illegible]uired for el[illegible] cast iron shells and curved float wh[illegible]

Diam. of fan in.	Cap area sq. in.	R. P. M.	Full Out[illegible] vol. cu. ft.	H. P.	[illegible]apacity vol. cu. ft.	
		1285	296	.072		
10.5	9.17	1820	420	.206		
		2230	512	.381		
		1140	429	.105		
12	13.5	1620	608	.300		
		1980	740	.555		
		950	664	.149		
14.5	19.0	1350	867	.420		
		1650	1040	.780		
		800	833	.204		
17.5	26.3	1130	1178	.579		
		1390	1450	1.08		
		700	1052	.260		
20	33.2	994	1480	.740		
		1220	1815	1.37		
		595	1846	.46		
23	58.7	842	2620	1.30		
		1030	3235	2.40		
		520	2660	.650		
26	83.3	736	3720	1.83		
		902	4680	3.41		

The motor efficiency is too well known to necessitate any explanation and may vary from 60 to 95% depending on the size of the motor. The fan efficiency is the ratio of the power delivered by the fan at its outlet, represented by the volume and pressure of air, to the power expended on the fan. This efficiency is seldom over 70% and for medium size fans is more often 65%. The fan losses occur in eddies formed at the inlet and outlet and within the casing, frictional losses, and a heat loss due to the compression of the air.

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low this new work had been in place about two weeks, and still had some shores beneath it. The removal of one of these shores showed that the floor was too weak to carry the load of the fifth floor, and the two forward panels in question fell. The materials of the concrete were good, but lack of thoroughness and first class workmanship in the concrete work is evident at several points in the structure. and together with the too early removal of the supports was responsible for the failure.

An accident which occurred last July in South Farmington, Mass., resulting in the death of twelve men and the total ruin of the building, was due largely to carelessness and too great haste in executing the work.*

The building was three and a half stories in height with side walls of concrete blocks made on the ground; the columns were of cast iron, floors and roof of concrete reinforced with Clinton wire cloth.

When the building collapsed the roof was being placed; the walls fell inward. and floors and walls were precipitated into the cellar.

There is no metal reinforcement in the foundation piers, which are soft and easily crumbled; the concrete was supposed to consist of a 1:3:6 gravel mixture, which seemed firm and solid on the outside but when the outer shell was broken the inside was soft enough to be readily scraped out with a shovel.

It appears from the evidence that the weight of the structure was sufficient to force the columns into the concrete of the piers, which had either not set sufficiently to withstand the load or the concrete was not properly made. The columns themselves were not broken. There was no building inspection, and this fact permitted carelessness in the hurried prosecution of the work which ultimately led to the disaster.

Several days before the final collapse, large cracks appeared in the walls and additional supports of 4x6 timbers were placed under the floors in order to temporarily relieve the columns, which were sinking, but the additional roof load was too great and the failure occurred as noted.

Numberless failures are constantly occuring, due to faulty design or poor execution, or both. which do not gain publicity because of their minor character and freedom from loss of life; yet these failures may be serious indeed for the owner. A sinking floor may fall or give such early indications of weakness as to call for a modification in the design with additional reinforcement, or stiffer beams and stronger columns or more of them. Possibly it

*Eng. News, August, 1906.

may require all of these, and even then the walls may be cracked or the floor so deflect that only a fraction of the desired load may be carried.

In these cases the owner frequently has no redress, as the contractor may be entirely irresponsible, but as long as owners continue to give their work to the lowest bidder simply because he is the lowest bidder without any other claim to consideration—just so long will these conditions exist.

A large amount of this work is put in on the contractors' own designs and the man who does the cheapest work gets the job. Whether he is a competent man, experienced in this work or not, seems to make little difference. In such cases the owner deceives himself, for there is in reality no competition under these conditions: In order to have competition all proposals must be based upon the same construction which obviously is not the case where every one bids upon his own design. Competition in this class of work is not always desirable, but if it be desired or necessary, the safest method to secure this and also to insure correct design and execution in reinforced concrete is to employ an experienced engineer to plan the work and supervise its construction, and even then poor results may follow if eternal vigilance is not exercised throughout the entire work.

Proper treatment of the concrete and a realization of the nature of the process of setting, is one of the requisites of success in structures of this character. No matter how well a building may be designed, a failure is always liable to occur unless the plans are closely and intelligently followed. This leaves an element of uncertainty in connection with reinforced concrete which demands the greatest care and faithful supervision in all its details, from the mixing of the concrete to the removal of the forms. The apparent simplicity of the construction has attracted large numbers into the field and we shall expect for some time to come that serious mistakes will occur even with the best intentioned and most careful of men. Many of those who have entered the field however, have no proper conception of the limitations imposed and rush into the work with a confidence which is sure to bring trouble. Here lies the dangerous feature of reinforced concrete construction.

The failure of the Bixby Hotel at Long Beach, Cal., and the collapse of the concrete manufacturing building at Kodak Park, Rochester, N. Y., were not due to mysterious and unknown causes, nor to reinforced concrete. The causes are easily recognized as among those already pointed out.

The Bixby Hotel is a six-story reinforced concrete structure

which collapsed last November, resulting in the death of ten men. Reports on this failure, as given by H. Hawgood, C. E., in the Engineering News and also by J. H. Leonard, C. E.. in The Architect and Engineer, indicate gross carelessness in the execution of the work, as well as serious errors in design.

The omission of proper reinforcement to carry the shearing stresses in the beams and girders, the failure to provide for shrinkage of the concrete, the absence of proper connection between girders and columns, the lack of transverse ties, the inefficient reinforcement of the columns and their slovenly construction: all these enter as indirect causes of this accident. While the direct cause was in all probability the premature removal of the forms, yet all these defects in design and construction contributed to the magnitude of the failure.

The verdict of the coroner's jury which investigated the cause of the accident was as follows:

"We, the jury, find the men came to their death November 9th, 1906, by being crushed by partial collapse of Hotel Bixby, under construction in Long Beach. We find from evidence given that such collapse was occasioned by prematurely removing part of the timbers supporting the fifth floor, and proceeding with construction of the roof before cement beneath was properly cured. We find no person criminally liable for such fatality."

Vigorous editorial comment in the Engineering News occasioned by this disaster is worthy of the careful perusal of everyone interested in the development of reinforced concrete construction.

The writer states:

"Carelessness, incompetence and unscrupulous skinning appear to have about reached the limit in reinforced concrete construction. Two failures of large buildings under construction, occurring within a fortnight of each other, both of which had their harvest of dead, is a serious blemish on the record of reinforced concrete.

"The practice that constructs buildings and bridges which collapse must be eradicated. The interests of every element of the engineering profession demand this, no less than public safety. We must seek out and identify the source of the conditions which are at the bottom of the trouble, and by eliminating it bring about improvement.

"Where are we to find relief? The theory is that the law which gives protection against rapacity and loose conscience so exercised as to harm another or injure the public. Has it done so in reinforced concrete building? The method of the law is to prevent by prescribing and enforcing penalties. The events of re-

RUINS OF THE EASTMAN KODAK COMPANY'S BUILDING.

cent years show no case. in the scores and scores of building disasters, where the law has laid its hand on the guilty and enforced its penalties. In many cases, to be sure, the antiquated and inadequate machinery or the coroner's office has made some ponderous movements, called "inquest" or "investigation," but with uniform fruitlessness. Public assignment of blame or criminal conviction have not been obtained.

"Such investigations are, under the prevailing system. conducted by the coroner with the aid of a jury of citizens. Both the coroner and his jury are as able (or unable) to hold views and pass opinions on reinforced concrete as to judge whether a fossil bone belonged to a dinosaur or a pterodactyl. These gentlemen listen to the architect's statement (if an architect be concerned in the case) that the design and materials were of standard quality. Then they hear the testimony of workmen employed on the job, who say, among other things, that no evidence of weakness appeared at any time previous to the collapse, and that the section which collapsed was constructed in the same way and with the same care as other sections which remained standing. Finally they listen to the reinforced concrete man, who "points with pride" to structures he has previously built without accident, and informs the jury that the reinforcing steel had a strength of 60,000 to the square inch. so that the structure should have (and, as test results on previous occasions showed, must have) been capable of carrying an enormous load with safety, whereas at the time of collapse it cvarried only a few planks and beams and half a dozen cement sacks. Thereupon, hearing further that sand and gravel sometimes have streaks of unnatural visciousness which may unaccountably produce a weak spot in the concrete, the jury brings in a verdict stating that the collapse was due to an unknown weakness in the concrete work, for which the jury was unable to hold any individual responsible. And having thus done its duty, the jury disbands. the coroner goes home satisfied and the matter is ended."

In view of these conditions, which we all recognize, it is most gratifying to note the recent report of the investigation of the accident which caused the death of four men November 21st at the works of the Eastman Kodak Company, Rochester. This building like the Bixby Hotel. was of the Kahn type of tile and reinforced concrete construction and was being erected by the designers, the Concrete Steel and Tile Construction Company of Detroit, Mich.

The coroner who investigated this failure called in expert advisers who by their knowledge and careful examination

assisted materially in locating the causes which led to the collapse. (For detailed report see Eng. News, Jan. 3. '07, and Eng. Record, Jan. 5. '07.)

The ruins show many indications of careless work and poor concrete. In one case a crevice occurs in one of the beams wide enough to insert the hand; this extends for a length of six feet or more along the reinforcing bar which seems to have prevented the concrete from flowing around and under it.

The report from J. Y. McClintock, C. E., one of the experts, states:

"Many of the posts show a horizontal joint of sawdust and shavings and paper. In column 2 at the level of the mezzanine floor I thrust in my knife blade two inches deep. In column 37 at the level of the mezzanine floor there is a joint of sawdust and shavings, horizontal. nearly if not quite through the section, into which a knife blade was thrust two and a half inches easily.

In the north face of column 37 there is imbedded a piece of wood showing 5 3-4 inches wide by about 13 inches long, and probably two or three inches thick, set up at an angle of about 45 degrees, so as to reach clear across the face of the post, apparently dropped into the wooden form along with the shavings and sawdust before the concrete was put in above the mezzanine floor. In the same column below the mezzanine floor the concrete is so poor that I dug into it with a small stick nearly two inches in one spot.

"In many places the steel bars show at the surface of the girders on the side.

The girder from column 2 to column 3, although on the face of the wall, bulges out so as to be deformed, apparently due to carelessness in bracing the forms.

"In column 47, the upper portion. about seven feet long, was of such poor concrete that we easily picked off with the fingers the upper two feet, and could crumble most of it in the fingers.

"I saw many places in posts and girders where the concrete was not filled with mortar, and had the open texture of a popcorn ball, indicating that it was put into the molds in too wet a condition.

"The cinder concrete on the roof has the characteristics of earth rather than concrete.

"In many cases the steel bars in girders do not connect or overlap over posts.

"The fallen posts show that there was no connection of the steel bars in the part of a post above a floor and below, and there are no dowels.

"The expert report to the coroner concludes that on account of the high stresses the design was defective; that the variations from the drawings show faulty construction; and that the weak spots in the concrete, the honeycombed character of the concrete in the lower part of many columns and the presence of leaves, sawdust, shavings and large blocks of wood in the concrete so as to impair its strength materially, show negligence in construction."

The verdict of the coroner is in part as follows:

"I find that the building collapsed because of the crushing of the lower portion of the steel-concrete column No. 47. Column 47 crushed because it was improperly designed for the material of which it was composed and for the duty assigned to it.

"I find the Concrete Steel & Tile Construction Co., of Detroit, guilty of criminal negligence in allowing pressures upon these columns beyond any safe limit.

"I find William Costello guilty of criminal negligence, because. while in charge of the construction for the Concrete Steel & Tile Construction Company, he allowed the cement to be put in the forms without proper tamping, so that holes were left in it, and allowed four steel rods to be put in a column where the plans called for six rods, and allowed four rods to be put in column 47 when the plans called for eight rods; and by gross and culpable negligence permitted leaves, sawdust, chips and blocks of wood to be put in the columns. thereby endangering the safety of the building.

"I find Perley S. Wilcox, assistant manager of the Eastman Kodak Company, who is an educated engineer and experienced in the construction of buildings, to be guilty of gross and culpable negligence; for the reason that, while the evidence shows he had and exercised control over the work of this construction on behalf of the Eastman Kodak Company, and had power to change the working plans and have removed defective construction and have careless workmen discharged, and even to stop the work; he, by gross and culpable negligence, allowed the contract to be violated so as to endanger life, by permitting column 47 to be constructed far weaker than was called for by the original plans made under his direction. and he was guilty of gross and culpable negligence when, recognizing his responsibility of inspection of the work in progress, he allowed to be employed a teamster, utterly devoid of experience in building, as sole inspector, without instruction as to the importance of the work he was inspecting, so that the moral effect of such inspection was bad, except, possibly, for impelling haste in the work rather than care for its integrity. He was guilty of gross and culpable negligence in not removing work which

was obviously defective, like blocks of wood and joints of sawdust at the base of columns.

"I also draw the following conclusions of fact from the evidence and study of this accident:

"First. The Kahn bars and similar bars, with shear members attached, are not suitable for columns, because of difficulty in properly tamping the concrete.

"Second: No steel concrete structure can be considered safe unless some reliable man is absolutely responsible for putting the proper number of proper sized bars in the positions designated for them.

'Third. The allowable stress upon steel and concrete in construction should be fixed by law, so that the safety of the public will not depend upon the cupidity of energetic contractors or parsimonious designers."

It is difficult to understand why Clause 3 has any bearing on the present case for the work was being erected under "a cost plus a fixed sum" contract, and the owner paid all of the bills, so there was apparently no inducement whatever to be parsimonious. Intelligent supervision of the work seems to have been woefully lacking and haste the principal desideratum. The lack of proper inspection engendered carelessness and as a result the building was ruined and four men lost their lives.

While the investigation of this accident has brought out many defects which may be more or less common in buildings of this character. and which have contributed largely to the weakness of certain members of the structure, yet the owners of this building ascribe the cause of the accident to the premature removal of the form work.

This opinion is corroborated by a report made to the Eastman Kodak Company by Mr. Edwin Thacher, and Mr. C. W. Marx. men of wide experience in concrete construction, who write as follows:

"We are fully convinced that the primary cause of the failure was due to the fact that the supports under girders and floor construction were removed too soon for that season of the year, your records showing that the concrete was only about three weeks old. The concrete throughout is of good quality but was too green (i. e., not sufficiently hard) to enable the respective members to even carry their respective dead loads with safety. Had the forms around the columns and sides of the large beams been first removed and the supports under girders and floor construction left undisturbed for a period of at least four weeks

longer it is our opinion that you would not have experienced the slightest trouble."

In considering the various failures of reinforced concrete, it will be readily seen that there is always a cause which is usually quite apparent. We do not believe there is any uncertainty about concrete construction, or that concrete buildings are dangerous. When such structures are properly planned by skilled designers, and erected by honest and experienced contractors who employ intelligent men and use good material, we shall have no uncertainty about the combination, and the result will be the safest of all structures.

IDENTIFYING GOVERNMENT MONUMENTS.

By E. W. KELLY, '07.

Since the greater part of a land surveyor's work either is the retracing of government lines, or has to do with the subdivision of sections, the ability to identify the original monuments is of great importance.

In old settled communities the exact location of corners has been well defined, as a rule, for years. but in the newer parts of the state a large proportion of these monuments have never been identified since they were originally placed. In this part of the country the work was done carelessly and hastily, and almost invariably with faulty implements. Too often there was rank dishonesty. In consequence, the original field notes are very unreliable as regards courses and distances; and hence the surveyor has no dependable guide in replacing corners other than the marks left "on the ground."

Fortunately the bearing trees, etc., are usually described with reasonable accuracy, and in consequence the attempt to restore a corner usually resolves itself into a search for bearing trees. That there is considerable "knack" to this is shown by the fact that in every party there is one man, or possibly two men. who discover all evidence not perfectly plain. Practice develops skill in this.

In timbered country the corners were almost invariably marked by stakes "tied in" to bearing trees, of which there was one in each section to which the corner was common, providing they were conveniently near. The bearing tree, or witness tree, was blazed about three feet from the ground, and on the blaze was inscribed the section, township, and range, in which the tree was located. Near the root another blaze was made, and inscribed "B. T." signifying "Bearing Tree." From this latter blaze the distance to the stake was measured. The blazes faced the stake, of course.

Naturally, the vast majority of the original stakes have decayed or have been removed, so that finding them without the aid of bearing trees is a hopeless undertaking. The proper procedure is to determine the location approximately by courses and distances. and then look for monuments. to determine the exact

position. In the search one cannot be confined closely to the neighborhood of the point where the corner ought to be. For instance, I remember finding a quarter corner on the Mesaba Range that was a trifle over 500 feet out of line.

Usually the bark of a blazed tree gradually grows in rolls over the edges of the blaze till it is completely covered, in most cases leaving a scar that is quite unmistakable. Upon cautiously chopping away this new growth, the old blaze with its inscriptions is exposed unchanged. In some cases, most often in pines and elms, the scar is obliterated. In this case, the only course of procedure is to make as close a guess as possible and then chop open the suspected tree on the side which should face the stake. If the tree has ever been blazed the scar or cleft will appear considerably before the blaze is exposed.

Often the tree has become hollow. In this case, particularly with oaks, the scars of the blazes usually appear as holes into the interior. The blazed surface is usually somewhat seasoned, and by inserting the hand through the holes, fragments of a sort of surface slab bearing the inscription may often be found in the debris at the bottom of the hollow. Red oaks have a trick of rotting after the blaze has healed. On this account it is advisable to preserve carefully the new tissue removed, for the inscription is very frequently found in raised letters, reversed, on its inner surface. In any case, if a tree of the proper description shows plain external scars such as follow blazing, it is considered good evidence.

It often occurs that a bearing tree has been attacked by fire. Sometimes the drying and hardening of the surface of the blaze seems to make it more able to resist the flames, sometimes the reverse. In some such cases I have found a hardened slab of wood, bearing the inscription, lying nearly uninjured among the ashes of the tree roots. On other occasions the blazed surface was the only spot to have suffered materially. Just what makes the difference is not apparent, for I have known both cases to occur with pines.

If only the merest fragment of inscription is left by fire, decay or the lumberman, it is still sufficient. The grooves left by the scribing iron are almost unmistakable, and those left by timber worms cannot be mistaken therefor. Consequently the search for evidence should not be abandoned till the most minute possibilities have been exhausted. This is well illustrated by some experiences of my own.

The notes for a corner called for a single bearing tree of more than a foot diameter. No timber but underbrush was stand-

ing in the neighborhood of the corner as determined by trial line; so our attention was confined to the ground. After thorough search, the only vestige found was an elongated green mound marking the fallen trunk of a tree far gone in decay. From its position it was evident that if it was the tree we sought, the inscription was underneath. We then began to pick the outer layer to pieces, examining piece by piece, and actually found a piece, the size of one's palm, that plainly showed a complete "S" and portions of some figures. Of course this crumbled to piecs shortly after being exposed to the air, but it had served its turn.

Another case called for a single pine, some hundred feet northeast from the corner. Upon several occasions this had been looked for unsuccessfully. The timber had all been cut four years previously, while the snow was not deep; so there remained only very low stumps. A thorough examination failed to reveal any external scars on the stumps in that vicinity. The date of survey was given as forty-nine years previous to the cutting of the timber. By counting this number of rings in from the bark, a rough estimate of the thickness of wood over the blaze was arrived at.

Perhaps I should explain that a low cut pine stump exhibits numerous marks of "pitch pockets" tangent to the rings, which exactly resemble a blaze cut transversely. We next looked for a stump of about the diameter called for, allowing for growth, having a pitch mark the proper distance in, facing southwest. This gave us enough conditions to eliminate most of the stumps from the problem. Finally one was found that satisfied them, however, and the axe disclosed the unmistakable remains of the lower part of the B. T. inscription.

Often mere spike-like stumps are all that remain of tamarack bearing trees, in marshes. These are always so covered with moss as to be hard to find, but they usually preserve at least a part of the lower inscribed blaze, on account of the moisture held by the moss.

After the location of the corner has been arrived at by bearing trees or otherwise, a search for the traces of the old stake should be made. A very good way to do this is to clear off the leaf mould and with a shovel or preferably a hoe remove the dirt layer by layer to the subsoil. The exact position of the stake is revealed by a round hole, fitted with black material, which extends directly downward and finally tapers to a point. It is distinguished from traces of roots by its vertical direction and by its sudden tapering.

In most difficult cases the evidence is destroyed in the taking. Consequently great care should be taken by the surveyor to exhibit all traces to the other members of the party, and to make a full and minute record of all evidence found. The names of all members of the party should be recorded carefully so that they may substantiate the record if necessary.

APPRENTICE WORK FOR TECHNICAL MEN.

W. T. RYAN.
Instructor in Electrical Engineering, University of Minnesota.

The average technical graduate has paid but very little attention to how things are actually done. When he goes out into the world he is liable to find that without experience he can't get a job and, of course, without a job he can't get experience. The outlook, to say the least, is discouraging.

There is no industry which is more intricate than the electrical art and none which is undergoing more changes. The man who would succeed in the electrical business should be adapted by education not only to grasp the past and the present, but also to keep pace with the rapid progress that is constantly being made.

Several of the large manufacturing companies realizing the above have made an organized effort to map out the territory which the technical graduate should cover in order to obtain the experience he needs in order to round out his theoretical training.

It is the purpose of this article to present the conclusions which I have arrived at in regard to the apprenticeship system as a result of personal experience and observation.

The policy of the large companies in offering shop courses, while highly commendable is, as carried on by some of them, open to more or less criticism. A representative of the company visits the school and offers to give positions to several of the senior class. Naturally the professors feel highly complimented and usually advise their students to accept. The shop course generally covers a period of two years. The hours are long and the pay is small. Does the experience gained justify the sacrifice? It may and it may not. It depends more on the man himself than upon anything else. All men are not built alike and should not be ground thru the same mill. I would say that about fifty per cent of the shop graduates feel enthusiastic over the course, whereas the other fifty per cent pass thru a long period of discouragement and in the end leave the shop with a sense of failure.

In England some of the large companies charge from $500 to $1,500 premium and require a man to work three years. If we compare the American system with this we must say that our companies give us from $500 to $1,500 worth of instruction and pay us while we are receiving this experience.

I was not long on the course before I found that there was more or less dissatisfaction felt by the apprentices. In fact, I did not feel quite satisfied myself at first. Things are not run right. The foremen do not appreciate our talents. We are not taken any more notice of than if we were machines. Where was the trouble? The foreman usually was a man who had attained his position as a result of years of experience in his particular line of work. It is not very surprising that he should have somewhat of a prejudiced opinion of those who would come into his department for, say two weeks, and then say that they had learned all they needed to know a week ago about the business that this man had probably spent a good portion of his lifetime learning. However, it was my experience that most of the foremen were not hard to get on with. By using a little tact and overlooking a few things you will always come out all right. Don't go and ask your foreman for a transfer while he is busy or just after he has finished cussing a disgruntled loafer. Every one cannot be in the best department at once. If you happen to be in a slack section there never are any objections raised to your going into another department and seeing what you can learn by observation provided you do not hinder men who are at work or turn your visit into a social call on a college chum.

With the company I was associated with the work generally given apprentices might be classified under the following four heads:

(1) Shop work.
(2) Testing.
(3) Engineering department.
(4) Correspondence department.

SHOP WORK.

The object of this work was to give us an opportunity to study the processes of manufacture.

The various sections of the shop are about as follows: (1) Commutators, (2) Brush-holders, (3) Controllers (4) Armature, Transformer and Field coil Winding, (5) Armature Coil Assembling, (8) Machining assembling and erecting of all kinds of A. C. and D. C. motors and generators, (9) Transformer assembling, (10) Mica Building Department, (11) Switchboards, (12) Rheostats and switches, (13) Punch shop, (14) Copper shop. (15) Instrument Division, (16) Electric Locomotives, (17) Power House, (18) Experimental Work, (19) Wiring Gang, (20) Foundry and (21) Winding Sections.

As a general rule technical men are not asked to work in the Punch Shop, Copper Shop, Foundry or Power House. Time and space would not permit me to discuss the various points to be observed in the different sections. I shall take one section and enumerate in detail the principal things to be taken note of in that particular section, leaving the others to your imagination.

Let us take one of the less attractive ones, say, for instance, "Armature coil Assembling." We might observe the manner in which the coils were insulated, the kinds of insulation used, their relative qualities, the kind and form of coils each was applied to, the quality of workmanship, the nature and cause of poor workmanship, who were and who were not doing a good quality of work, the reasons why; such as carelessness, inability, lack of experience, too great a desire to get a certain amount done perhaps due to the premium system; the different classes of tape used, such as rubber, treated cloth, untreated cloth, friction tape, etc., the qualities of each, such as the ability to withstand mechanical injury due to rough handling for the friction tape and high dielectric strength for the treated cloth, the relative amount of space occupied by copper and by insulation, kinds of insulating varnish used, methods of applying, such as dipping or applying with a brush, air-drying varnishes, when used and why, varnishes which can be dried only by baking when used and why, the tests applied to the different coils, the percentage that break down, etc., etc. There is a tendency to cut the shop work short due to the demand for men on tests and in various offices The average man does not spend over six months in the shops.

TESTING.

The two functions of the testing department are, first, to furnish the engineering department with information regarding the operation of machines so that the design may be checked with the actual performance, and second, to maintain a high standard of workmanship and material in the factory. This department is under the control of the manager of works but the engineering department specifies the tests to be made and passes upon the results. In the case of first machines of a particular design, special machines and all large machines, the results are submitted to the engineer in the form of curves and must be approved before the machines are shipped. These curves in the case of small machines are filed and in the case of a duplicate machine if it checks sufficiently well with the first machine of its type it is shipped without reference to the Engineering Department.

The work on the test floor is perhaps the most beneficial part of the course, and at least six months should be spent in this department. It is here that we find out what the defects are and what tests are required to find them The finished machine in addition to doing its work should present a pleasing appearance to the eye and it should also have sufficient strength, mechanical as well as electrical, to withstand the various strains which may be put upon it in actual service. A vast amount of information regarding the performance of railway motors, D. C. Motors and Generators, Synchronous Motors, Alternators, Rotaries, Induction Motors, Turbo-generators, single phase commutator type Motors, Motor generator sets, etc., may be collected in this department. Confidence in one's self is obtained by handling large machines, also the ability to do such operations as synchronizing, paralleling, pumping back into the line, etc. When working on the test floor don't do as at least three-fourths of the apprentices do, simply make connections in a mechanical way and be an observer of readings. Take a sheet of cross-section paper and plot the readings as taken, so that you will know what you are doing. Nine cases out of ten the troubles found can be remedied by use of a little common sense. If the performance is not right you find out why instead of referring it to the Engineering Department.

ENGINEERING DEPARTMENT.

It is this department that the various kinds of apparatus are designed. The Engineer not only designs the machine but also passes upon the results of its test, hence he is the man who more than any one else is responsible for its satisfactory operation. The Engineering department is divided into the following divisions: (1) Transformer, (2) Power, (3) Industrial, (4) Detail and Supply and (5) Experimental Department.

The work of the Transformer Division consists of the design of all classes of Transformers from one Kw. up to several thousand, also series and voltage transformers. Each man follows a certain line. For example, one man designs Type N, another Type OD, another Air Blast Transformers, etc. In the Industrial division standard machines of standard sizes are taken care of. The Engineer always makes the standard machine meet the requirements of the customer with as few changes as possible.

In the Detail and Supply Department all kinds of details, arc lamps, fan motors. small power motors, etc., are taken care of.

The work of the apprentice in the Engineering Department usually consists in furnishing the shop foreman with the data

necessary for them to have in order that they may go ahead and build the apparatus. This information is filled in on suitable blanks especially made for the purpose. The work of the experimental division is devoted to original research work, testing of the materials of manufacture and the conduction of experiments along lines where special information is desired by the Engineering Department in order that they may intelligently design their apparatus.

CORRESPONDENCE DEPARTMENT.

The work of this department is devoted to the handling of orders and correspondence in general. I believe I can best point out what you might expect in this department by outlining the scheme in vogue for conducting the work. It includes the following:

1. Orders and correspondence relating thereto.
2. Negotiations pending.
3. Letters awaiting replies from the works.
4. Letters awaiting replies from the District Office.

ORDERS AND CORRESPONDENCE RELATING THERETO.

Embraces: All orders sent in from the District Office, whether on contract or District Office forms. Routine:

(a) Acknowledge receipt of order where General Order can be entered at once. The General Order gives the shipping instructions, terms, etc., also the information necessary to identify the apparatus. If the apparatus is in stock the storekeeper goes ahead and ships it as per the instructions of the general order. Otherwise the general order must go to the Engineering Department who in turn furnishes the shop with the information necessary to build the apparatus. It is then up to the shop to build the apparatus and deliver it to the testing department. If the Engineer passes the test it is then delivered to the storekeeper who ships it. It is "up to" the correspondent to see that the work is kept going in the various departments.

(b) Enter the general order, five copies ordinarily, seven where time and expense of an Engineer to erect the apparatus are included. The copies of the general order are distributed as follows:

Original—Storekeeper.

One Carbon—Sales Record Department with proper information.

One Carbon—Traffic Manager.

One Carbon—District Office.

One Carbon—The correspondent himself.

Where the time and expense of an engineer for erection purposes are included two copies are sent to the construction department.

(c) The customer's order, immediately after being entered in the factory is forwarded to the following:

(1) Sales Department (only when cut in price, dealer's price or commission is embodied.)

(2) Credit Manager.

(3) Head of Correspondence Department (only in cases where the amount exceeds $1,000 or where the order is in contract form.)

(4) Acting Vice President for executive approval (only in cases where the amount exceeds $1,000 or is in contract form.)

(5) Correspondent.

(6) Audit for filing and return customers copy to District Office.

(d) Make record of dates for shipment in date book and see that they are checked so that the District Office may be kept fully advised as to the condition of the order.

NEGOTIATIONS PENDING.

Embraces: Correspondence relating to new propositions on which quotations, etc., have been made. The papers should be kept together properly subjected and filed in vertical filing cabinet. When it becomes inactive transfer to pneumatic central.

LETTERS AWAITING REPLIES FROM THE WORKS.

These are kept fastened in a drawer for ready reference.

LETTERS AWAITING REPLIES FROM THE DISTRICT OFFICE.

Thase are generally kept in the correspondent's desk properly marked. Some men prefer to put them in the files.

RECORD OF ORDERS.

A card index is kept in each division by means of which a record is kept of all orders entered in the factory. These cards are made up by the division's head stenographer and by her kept up to date. The cards are indexed according to customer and filed alphabetically. On receipt of the order by the head of the divis-

ion. name of customer and the apparatus in general is taken off, after which the order is turned over to the correspondent. Copies of the General Order returned for Office Records are delivered to the division's head stenographer, so that record of the stock orders (shop orders) may be placed on a card, after which the general order sheet is turned over to the correspondent.

The works are so large and the system so complicated that many of the apprentices fail to grasp the connecting links between the various departments, thus obtaining not only a disjointed collection of information but also a disjointed training, which is not of any great practical value to them. Study the system. Study the people you are thrown in contact with. If you see things which you think ought to be changed do not be too hasty about saying so, you may change your mind later on or possibly you may be in a position some day to actually be able to apply the remedy.

In conclusion I wish to add that if you want to advance from the ranks of the apprentices to something better at a higher salary you got to show the company that you are able to deliver the goods. I remember one dissatisfied man who said to me "I am not going to do more than sixteen cents worth of work an hour." I wondered if he realized that he wouldn't get any more until he had demonstrated to the company that he was worth more.

THE ST. CROIX FALLS POWER PLANT.

By WADSWORTH A. WILLIAMS, MINNEAPOLIS, MINN.

A mine on a mountain, so inaccessible that it cost more to deliver coal for power than the output of the mine could pay for, was the prime mover in the beginnings of the science of modern high tension, long distance transmisson, that has done and is still doing more to revolutionize our present power systems than any one thing since the time of Archimedes. The owners of this mine, in San Miguel County in Colorado, conceived the idea of developing a water power two thousand feet below and three miles away, and, instead of hauling coal to the mine at enormous expense, of transmitting the electrical energy over slender copper wires. Even with the imperfect equipment the practicability of alternating current transmission was established and the startling fact announced that remote water powers could be made to send their forces miles away to manufacturing centers. This is now hurrying forward the electrical age. Even though this was sixteen years ago, and untold millions have been invested in such enterprises, the public still are wont to regard such plants as possessing an air of mystery, and have scarcely admitted the reality of it all.

The development of a city now depends largely upon its being able to utilize such water powers, and the tendency is toward the use of electrical energy for all purposes, especially in the field of light, heat, and power, thus doing away with the tall chimneys belching forth their volumes of smoke, like volcanoes, in the heart of the business district.

Minneapolis is now supplied with electric current from such a source. Fifty years ago a few hardy pioneers settled on the banks of the St. Croix river at Taylors Falls. Such a magnificent water power would certainly attract large manufacturing plants and a great city would grow up there. The great power is now developed; but, instead of supplying great factories at that location and building up a large population, the power is conveyed to Minneapolis, forty miles away, by three half-inch copper strands, and a station superintendent with a few assistants is all the population added to the village.

The villages of Taylors Falls and St. Croix Falls lie on opposite banks of the St. Croix River. The world famous Dalles of St. Croix lie below the villages, and, because of their remarkable natural scenery, were made part of the State Park Systems in 1895 by acts of the legislatures of Minnesota and Wiscconsin.

The Minneapolis General Electric Company under the management of Messrs. Stone & Webster of Boston owns and controls this power plant. After careful preliminary surveys, under authority of congress and the legislatures of the two states, the construction work was begun in the summer of 1905 and the plant was completed in the fall of 1906.

The dam is built of concrete 50 ft. high and 750 ft. long, and the station, also of concrete, reinforced, is built on the back of the dam at the Wisconsin end. The storage from the main dam forms a beautiful lake eleven miles long and half a mile wide, while. further up the river, the same company owns the Nevers dam with a storage supply that altogether makes a lake twenty-two miles in length.

A few unique features may be mentioned. On the Minnesota side it was necessary to construct a concrete dike a thousand feet long to protect the low land above the village of Taylors Falls.

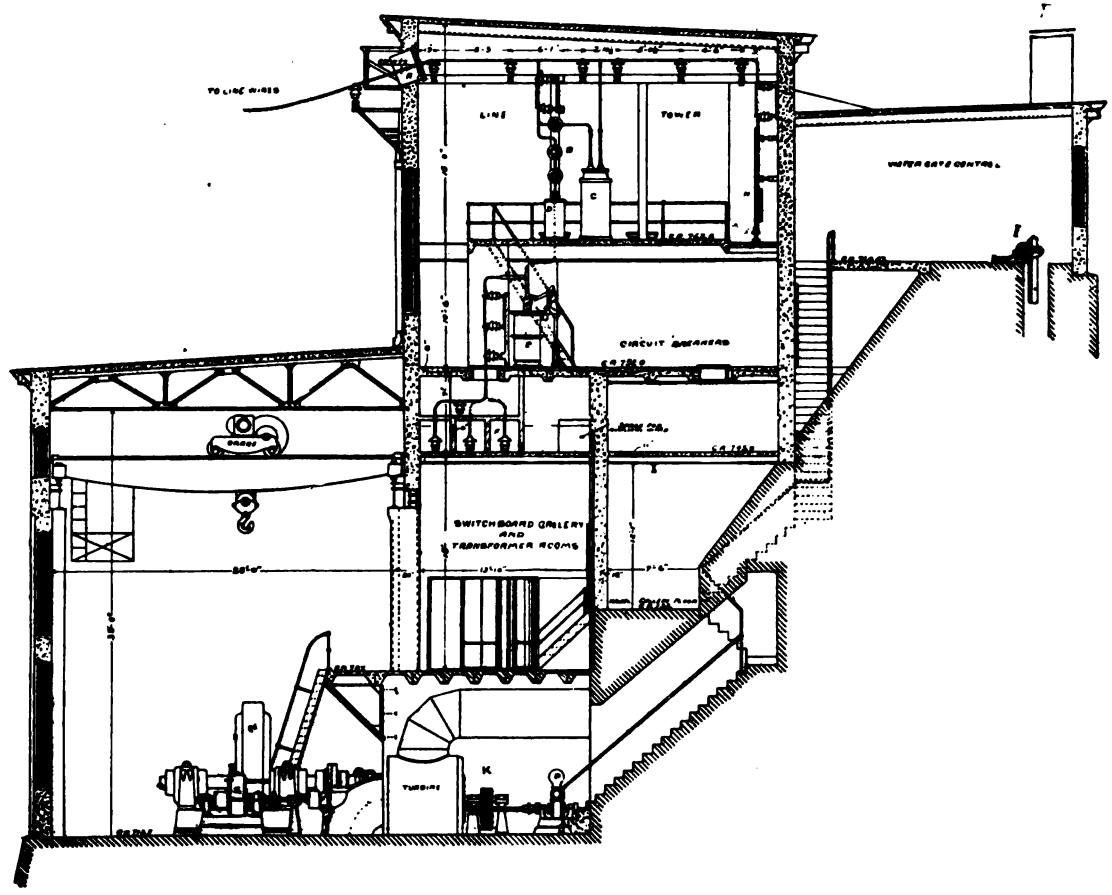
The fishway is a series of wooden boxes with openings a short distance the one above the other. by which it is possible for the fish to climb up or down, a foot at a time, the steep face of the dam.

The "bear trap" is situated on the Minnesota end. This is a section of the dam made of steel which can be raised and lowered to allow the passage of logs down the river. For the floating of logs, though rapidly diminishing, is still an important use to which this river is put. This moveable dam takes its name from the first moveable dam ever built. During the experiments on that dam the builders would answer the curious questioners that they were building a "bear trap," and this name has stuck to it ever since.

The river will develop ultimately 25,000 horse power. The initial development, however, is for 12,000 H. P., and this portion of the plant is already in operation. The foundation and steel work for the addtional generators are already installed and the machinery will be placed in position as needed.

Under the effective head of 55 feet, the water goes from the forebay through the iron penstocks of which there are four in use, each 14 ft. in diameter; thence to the waterwheels. draught tubes and tailrace. The penstock for the exciter is four feet in diameter.

POWER HOUSE AND TAIL RACE AT ST. CROIX FALLS, WIS.



CROSS SECTION OF POWER HOUSE AT ST. CROIX FALLS, WIS.

The water wheels are of the Victor type, 36 inches in diameter, with four runners to each unit. The water wheel governors are of the Lombard type, each capable of exerting a pressure of ten tons in opening and closing the water gates, and one is supplied for each water wheel.

As all of the wheel casings are imbedded in solid concrete, access to the wheels can only be obtained by vertical tubes, the upper ends of which open into a small room behind the switchboard. A trolley hoist directly above these tubes provides for the installation and removal of the parts of the water wheels.

Direct connected to each of the four water wheels is a 2500 K. W. Westinghouse generator. The specifications require that each generator shall be capable of developing for several hours without injury 3125 K. W., or, an overload of 25%. These generators are 2300 volts, 60 cycle, 3 phase, with revolving field, and run at a nominal speed of 277 r. p. m. This speed may be increased to 550 r. p. m. without causing excessive strain on the revolving parts.

The exciter water wheel is direct connected to a 100 K. W., 125 volt Westinghouse generator, running at a speed of 525 r. p. m.

The generators are connected through remote control oil switches each to a bank of three 875 K. W. Westinghouse transformers, which step up the voltage to 50,000. These transformers are oil insulated and water cooled. It was necessary to observe the greatest precaution in setting up these transformers to eliminate every trace of moisture, both from the transformers and the insulating coil. To accomplish this, the windings and cores were kept at 100 degrees Centigrade for a week, while the interiors of the transformers were in vacuum.

In a little room off the gallery, above the generators, is the main switchboard, consisting of two panels for the exciters, four panels for the generators and transformers combined, one panel for the transmission line to Minneapolis, and one for the local line to St. Croix Falls, and one for a total panel. The board is equipped with Standard Westinghouse instruments. No high potential wires are connected to the switchboards, the maximum potential here being 110 volts. There are nine oil switches of the solenoid type controlled by the switchboard.

Crossing the river gorge, in a long span, the transmission line is supported by two steel towers. At other places, where the line crosses lakes and rivers, steel towers are also used. The line, almost an air line for 40 miles, is built on a 60 ft. right of way, land which the company owns in fee. The pole line is built 10 feet

from one side, and the intention is to build a duplicate transmission line ten feet from the other side. The company's private telephone line is also on this pole line.

The transmission line required 1800 extra strong 50 foot Idaho cedar poles and 25 steel towers for its construction. Half a million lbs. of 4-0 B. & S. 19 strand copper wire supported on huge procelain insulators, one on the pole top and two on a cross arm, provide the conducting line. The three wires are 72 inches apart and every three and one-half miles the relative position of the wires is changed to keep the static relation uniform.

More than a year before the station was in operation the line was built and carefully patrolled by the Engineers, who were making exhaustive tests on the problem of lightning protection. Among the different types of lightning arresters experimented with were the low equivalent multi-gap arrester, the horn type arrester, overhead wire over the transmission line grounded frequently, and lightning rods, some on poles beside the transmission line and some on the transmission poles themselves.

In all these methods the wires leading to ground have a small gap in which is inserted a small piece of paper. The spark punctures this paper, and the kind of puncture indicates to the trained eye the kind of electric discharge. For instance, a small distinct puncture the size of a pin point indicates a static discharge which might be caused either by lightning, wind friction on the line, or a static leakage on the line itself across the insulators to ground. A hole with charred edges would indicate that the line current itself had passed along the wire containing the tell-tale paper. This paper is about two by three inches in size, and some of the discharges make holes requiring a microscope to detect them, while some nearly consume the paper altogether. Different colored papers are used for the different protective apparatus. The papers are charged after every thunder storm and the results compiled in graphic charts by the Engineers. These experiments show the character of the disturbance to which the line is most subjected and give a comparative record of the relative efficiency of the different types of protective apparatus.

The high tension line ends at the new substation, located at Broadway. N. E., and city limits. Here, the current is stepped down by means of nine transformers; thence, three lines conduct the current to the company's main local station and the wholesale power district, where a large part of the power is already contracted for.

GENERATOR ROOM.

Transmission Line Looking East Across Long Lake.

Linemen Completing Last Span Transmission Line.

NOTES ON THE CALIBRATION OF A WHEATSTONE BOX BRIDGE.

B. E. SMITH, '07.

Wheatstone box bridges may be obtained on the market, guaranteed by the best makers to be correct within about .04 per cent in the rheostatat arm and .02 per cent in the ratio arms. Such guarantee, however, is not always to be relied upon. Moreover, the adjustment of a box may change with time or the box may be accidentally injured so as to alter the resistence of its coils. Again occasions frequently arise in research work when measurements involving the greatest refinement must be made in which the allowable error is less than .01 or even .001 per cent. In any of these cases some means is required by which the absolute and relative values of the various resistances of the bridge may be checked.

The work for which the bridge is intended will naturally determine the degree of refinement and hence the method of procedure. For ordinary engineering measuremnts an accuracy of .1 to .5 per cent is sufficient, and a cursory which in all probability would reveal a greater error is all that is necessary. Such tests can be made with apparatus available in any commercial plant. When, however. for research purposes, a calibration of special nicety is demanded some additional apparatus is required. Accordingly it will be assumed that a sensitive galvanometer, an ordinary resistance box, and a large standard resistance are available.

If we assume that the bridge is mechanically perfect, i. e., having no open circuits, and having the contact surfaces so ground and cleaned[1] that the resistance of the plug contacts is negligible, this calibration may be carried out to a refinement limited only by the patience of the observer. Under this assumption every source of error in the box must be due to the fact that some coil having a nominal resistance of, say, n ohms has in actual fact a resistance of n+q ohms, where q is a small quantity either positive or negative, as the case may be, depending in magnitude on

[1] A very good way to clean contacts is to use a soft cloth moistened with a very weak solution of oxalic acid and afterward rinse with clean water. Dry carefully. If the contacts are not too dirty a dry woolen cloth is very satisfactory.

the percentage error in that particular resistance. If, then. we represent each individual resistance in a box by the sum of two resistances, the first of which is the nominal resistance, and the second quantity of unknown magnitude equal to the actual difference between the true and nominal resistances, our task resolves itself into the problem of determining the true values of these small unknown terms.

Passing from generalities to a concrete case let us represent the individual coils of a box by Roman numerals in one column, in a second column let us put the nominal values, and in a third the sympols representing the small unknown terms, which added to the nominal give the true resistances of the coil. Thus for the rheostat arm:

THOUSANDS		TENS	
I.	$= 10000 + m$	IX.	$= 100 + z_1$
II.	$= 4000 + w$	X.	$= 40 + w_2$
III.	$= 3000 + x$	XI.	$= 30 + x_2$
IV.	$= 2000 + y$	XII.	$= 20 + y_2$
V.	$= 1000 + z$	XIII.	$= 10 + z_2$
HUNDREDS		**UNITS**	
V.	$= 1000 + z$	XIII.	$= 10 + z_2$
VI.	$= 400 + w_1$	XIV.	$= 4 + w_3$
VII.	$= 300 + x_1$	XV.	$= 3 + x_3$
VIII.	$= 200 + y_1$	XVI.	$= 2 + y_3$
IX.	$= 100 + z_1$	XVII.	$= 1 + z_2$

If now we wish to determine accurately the relative values only of the different resistances, the correction term m for the 10000 ohm coil may be neglected as experience has shown that the highest resistances are least liable to be in error and for ordinary commercial purposes it is simpler and usually sufficient to assume that the highest resistance in the box is correct. In this case, therefore, m=o. If however the absolute as well as the relative values are desired to a great degree of accuracy, the resistance of the 10000 ohm coil must be determined by comparison with a standard resistance.[2] The value of m is then known, being the difference between the true and nominal values of I.

The bridge is connected in the usual way. using a sensitive galvanometer. and placing in the unknown resistance, or X arm a resistance, part of which is an ordinary resistance box, adjustable by small divisions. Introduce, first. coil I into the rheostat arm, and use such a ratio in the ratio arms as will make the resistance in the X arm at least 1000 ohms. Adjust the resistance of the X

2 When a resistance is to be measured by direct comparison with a standard, the two should preferably be of about the same denomination in order to secure the best results. Hence that particular coil should be standardized in this way the nominal value of which is nearest that of the standard available. It need not be the largest coil in the box, but the larger the better.

arm till there is no deflection. The limit of accuracy to which the adjustment is made is easily obtained from the conditions of the adjustment. Then leaving the ratio arms and the X arm unchanged, plug out coil I and introduce in its place coils II. III, IV. and V, which together have the same nominal value as coil I. If the coils have been accurately constructed, i. e., if the quantities m, w, x, y, and z are all equal to zero, the system will still be balanced. This, however, will rarely occur, and the adjustable resistance of the X arm must now be modified by plugging in or out some small resistance, A, till the balance is restored. If A has such value that it cannot be introduced exactly by any combination of the plugs in the resistance box. its true value can be ascertained with sufficient exactness by interpolation. This done we have the following equation:

$$I=II+III+IV+V-A$$

i. e., $10000+m=4000+w+3000+x+2000+y+1000+z-A.$

which reduces to $w+x+y+z=m+A.$

For example: Suppose that in order to restore the balance it was necessary to introduce 3 ohms into the X arm; then we have $A=3\pm.003$ ohms, because in a box built by a reputable maker the error is almost certainly less than .1 per cent, i. e., .003 ohms. This quantity is so small that by neglecting it we introduce an error of only $\frac{.003}{1000}=.0003$ per cent in the calculated value of V, the smallest coil involved. Hence the nominal value of A may be taken as the true value of the resistance plugged in to balance the circuit.

In a similar manner we may proceed balancing various resistances against others of equal nominal resistance in the rheostat arm till we have a full set of equations, as follows:

$$I=II+III+IV+V-A$$
$$II=III+V-B$$
$$III=IV+V-C$$
$$II+V=III+IV-D$$

These reduce to,

$$x+y+z+w-m=A$$
$$x+z-w=B$$
$$y+z-x=C$$
$$x+y-w-z=D$$

Solving we have for the correction terms of the thousands coils:

$$x=\frac{3A+3m+2B-4C+D}{10}$$

$$z=\frac{B+C-D+x}{3}$$

$$w=x+C-B$$

$$y=C-z+x$$

In which A. B. C. and D. are the resistances plugged in to balance the system, and m is a known quantity or zero. The equation for the hundreds, tens and units coils are obtained in the same way. The correction term for the highest resistance in each set being known as it is the lowest of the preceding set.

In this manner the relative values of the rheostat arm resistances may be obtained to any desired degree of accuracy and the absolute values to as high a degree as it is possible to determine the correction term m. Morever, the accuracy of the results is not impaired by any amount of error existing in the ratio arms provided only that the ratios used remain unchanged while each set of readings is being taken. This done, it remains to check the ratio arms.

Let us consider that our ratio arms A and B are nominally alike each having four coils, I, II, III, and IV, of the nominal values 1000, 100, 10, 1. Inasmuch as the absolute values of these resistances are never used but only their ratios it is evident that we are concerned with the exactness of their relative values only. Hence any one at convenience, say $I\alpha$ may be assumed standard and exact and the others expresed in terms of it.

In order to check these ratios we proceed as follows: The adjustable resistance used above in the X arm is replaced by some large standard resistance R. The coils $I\alpha$ and $I\beta$ are introduced into the ratio arms and the calibrated rheostat arms adjusted till the galvanometer shows no deflection. If, then, the true reading of the rheostat arm is, say, R+s we have,

$$\frac{I\beta}{I\alpha}=\frac{R}{R+s}$$

If now, as is usually the case, s equals zero within the required limits, $I\beta$ is correct also. In the same way we may compare the hundred ohm coils and the ten ohm coils. Experience has

shown that almost invariably, unless the coils have been mis used, these ratios are correct to within the limits to which they have been guaranteed, so great is the care taken by the manufacturers with these most important parts of the instrument. If they do so check it is very improbable that the cross ratios, 1000 : 100, and 100 : 10, involve any greater error. However, these ratios should be checked against each other in the same way as the others. So far in this discusion it has been assumed that the box was not provided with facilities for reversing the ratios. If, however, the ratios can be reversed the use of the standard resistance may be dispensed with. This may be done also in any case where the ratios appear to check very closely as the chance of error is then very slight. Experience shows that owing to various causes the percentage error found in the one ohm coils is much greater than in the others. When the above ratios do not check and the arms cannot be reversed the absolute resistances of both of the 1000 ohm coils and one of the 100 ohm coils must be obtained by comparison with the standard. From these values we may determine the ratios $I_\alpha : I_\beta$ and $I_\alpha : II_\beta$, and from these ratios by comparisons similar to those above, all the other ratios may be calculated.

The scheme outlined above was worked out by Prof. A. Zeleny of the Physics Department for the purpose of calibrating a Leads & Northrup box bridge, which was to be used in investigating the electromotive forces developed in thermo-electric couples by small differences of temperature. The results obtained were most gratifying; the various corrected resistances of the bridge checking each other to within .001 per cent.

EDITORIALS.

It has been the aim on the part of the Board of Editors to publish the 1907 Year Book at a somewhat earlier date than has been the practice in former years. There has been a twofold object in view in doing this.

In the first place, it was desired to put the Book in the hands of its readers a sufficient length of time before vacation opens to enable them, while the Book is still new, to discuss, with the alumni and outgoing students, its merits, as well as the merits of the articles. They will thus be better able to enjoy the greatest benefits which may be effected by its contents.

Secondly, it was thought that a better opportunity may be given the succeeding Board of Editors to profit by the experiences of the present Board.

The intention of the Board has been fulfilled.

That the Board has been successful in its object has been, in a great measure, due to the promptness of the contributors of articles in sending in their material. The Board hereby takes pleasure in expressing its appreciation of this promptness.

In this connection we wish particularly to thank Profs. Constant, Flather and Springer, who have repeatedly favored the Year Book with very able and timely articles. We feel. also, greatly indebted to all contributors to the 1907 Year Book.

Among the contributors are several students, articles by whom have been published as an experiment, with the hope that the latter will prove successful. We trust that student contributions may be made more numerous in future issues of the Year Book. The Year Book may then be. what the founders of the Society intended it to be, a publication for the students by the students. Thus the value of the articles to the students will be increased; to the reader, as written by a fellow student, and to the writer, as a result of the labor and study in preparing the article.

The Frontispiece of the 1907 Year Book is a representation of the Soldiers' Monument at the University of Minnesota. This monument was dedicated on Memorial Day, 1906, to the memory

of those former students of the University of Minnesota who, as members of the Army or Navy of the United States during the Spanish-American War, gave up their lives on the field of battle or died from the effects of service in the war.

The Monument has been erected through funds subscribed mainly by the students and alumni of the University of Minnesota. It is a fitting tribute from them to the courageous and patriotic spirit of all student soldiers, not only the dead, but also all those who have, at any time, served in either the military or naval department of the United States.

No true story of the erection of the Monument is complete unless it tells of the part taken in this matter by Prof. A. E. Haynes. As Chairman of the Soldiers' Monument Committee, Prof. Haynes devoted untold time and labor to the carrying out of the project. When subscriptions were slow and the light of his cherished ambition shone but dimly in the future,—far distant as it appeared,—he never wavered, but patiently and untiringly, like a true Minnesotan, labored toward the end which has resulted in giving to the University of Minnesota this Monument, of which every Minnesotan, student or alumnus, may feel justly proud.

In the near future the College of Engineering, we expect, will have its head in the new Engineering Building which the Board of Regents has recommended and toward an appropriation for which the state legislature seems to be favorably disposed.

There is no doubt that this building is absolutely necessary. The College of Engineering has long since outgrown the Mechanic Arts Building, which had been its first home, as well as the shop and laboratory buildings. The latter were originally intended for engineering museums, but are now being used as temporary quarters for office and class rooms.

As an instance in point of the growth of the College, we may take the mechanical laboratory, which also embraces the hydraulic laboratory. This is now located in the basement of the Mechanic Arts building. The work there done, however, in order that it might be done satisfactorily, with proper facilities and without undue inconvenience, would require a building by itself. This is saying nothing of the apparatus which, though required for the course, is not provided on account of lack of space and appropriation.

It is to be hoped that the legislature will be fully informed and convinced of the immediate necessity of a new building for the College of Engineering and will not fail to act favorably in this

regard. It will require but little effort on the part of the alumni to place the matter properly before the state legislators, and, without a doubt, their attempts in this direction will prove very effective in bringing about the much desired and greatly needed appropriation for this building.

In regard to the progress of the Engineers' Society, it may be said that the Society is now in a very flourishing condition. Its membership has been very considerably augmented, and a genuine interest is being taken in its affairs.

One thing, however, the Society stands very much in need of and that is funds to procure lecturers to address the Society. The treasury of the Society is quite inadequate for this purpose. A movement is on foot to have the Board of Regents appropriate annually a sum of money which would be large enough to defray the expenses of at least seven lectures a year. The work which the Society has done as an aid in training students of the College of Engineering has been very valuable. The series of lectures, given with the help of the necessary funds, would very materially increase the results in that direction. The Board of Regents, in making this appropriation, would be conferring a great benefit on the College of Engineering as a whole.

At the solicitation of some of the professors and various of the alumni, it has been deemed wise to have this edition of the Year Book embrace a Directory of the Graduates of the College of Engineering. It was also thought that such a directory would prove to be of great assistance to both students and alumni in communicating with alumni and keeping alive a Minnesota spirit, and that it would enable undergraduates to be more easily benefited by the experience of graduates. The Directory has been compiled with a great deal of care, and, if there be any errors, we hope that they will be overlooked. It seems that the Directory ought to prove profitable in more ways than one, and, that being the case, we would recommend the insertion of the Directory in every edition of the Year Book. With the co-operation of the alumni this ought to be made possible with very little effort.

PROCEEDINGS OF THE SOCIETY.

The society began its work for the year with an open meeting held for the purpose of interesting the Engineering College as a whole in the Society. Short addresses outlining the purpose of the Society and its work were given by Dean F. S. Jones and Profs. Hoag, Flather and Shepardson. The results of the meeting were soon apparent in the increased enthusiasm manifested in the doings of the Society. The Society now boasts of a membership which is the greatest in its history and far surpasses that of the last few years.

Following the plan brought out last year, programs by members of the Society were rendered after the regular business sessions. These were as follows:

NOV. 3, 1906.

"An Idaho Power Plant".....G. W. Uzzell, '07
"The Construction of a Concrete Reservoir".....J. Nekola, '07
"Railroad Maintenance of Way".....L. A. Jones, '07

DEC. 6, 1906.

"Engineering Monuments".....E. W. Kelly, '07
"Experiences With a Small Marine Gasolene Engine"—
H. C. Estep '08

FEB. 7, 1907.

"Lightning Protection of the Taylors Falls Transmission Line".....M. D. Bell, '07
"Duties of An Assistant Engineer".....H. D. Haverson,'07

MAR. 7, 1907.

"Tests of an Electric Light Plant".....R. A. Rawson, '07
"The University Storage Batteries".....B. E. Smith, '07
"Sewage Disposal".....C. D. Batson, '07

On Nov. 22, 1906, Mr. C. H. Harris of the Minneapolis General Electric Co. gave a very interesting and comprehensive lecture on "The Development of Power at Taylors Falls."

On the evening of Dec. 13th, 1906, at the St. Anthony Commercial Club, an informal gathering of the members of the Society took place, the number present being sixty-five. After light refreshments had been served, a number of toasts were responded to. Mr. L. A. Jones acted as toastmaster, the speakers of the evening being Messrs. M. D. Bell, '07; C. D. Batson, '07; P. P. Furber, '08; H. N. Gage. '08; R. W. Kerns, '07; B. E. Smith, '07; W. W. Spring. '07; C. Sternberg, '07, and Ell Torrance, '09.

The annual banquet will take place in May and it is expected to be the success it has been in years past.

March 27, 1907.

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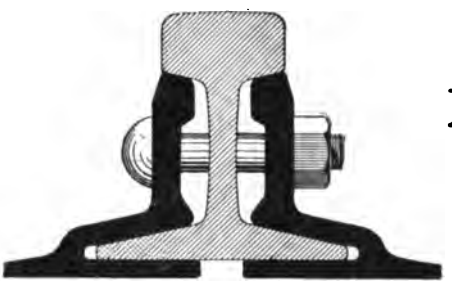

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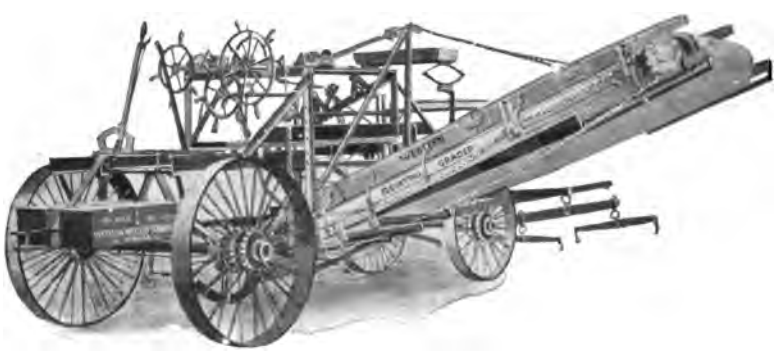

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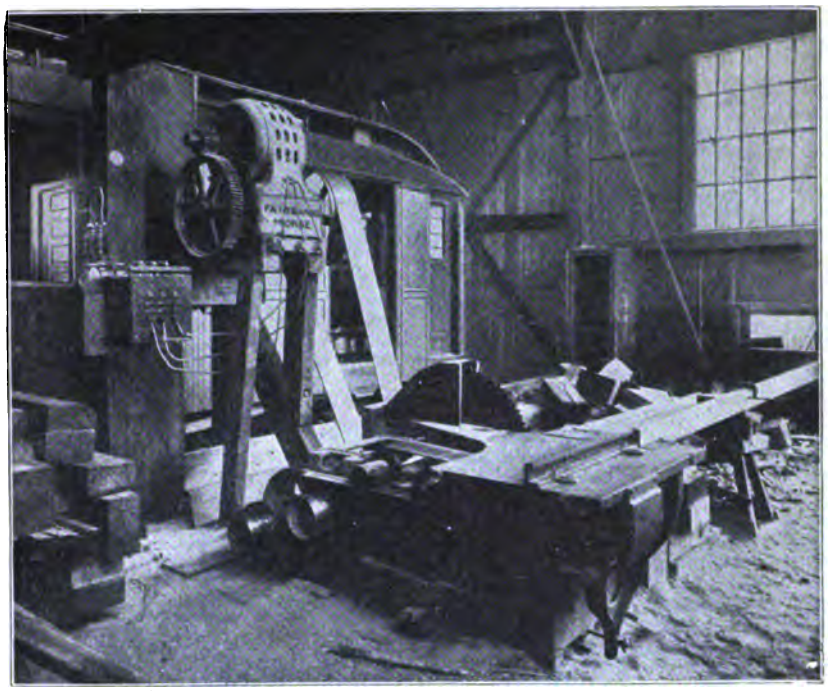

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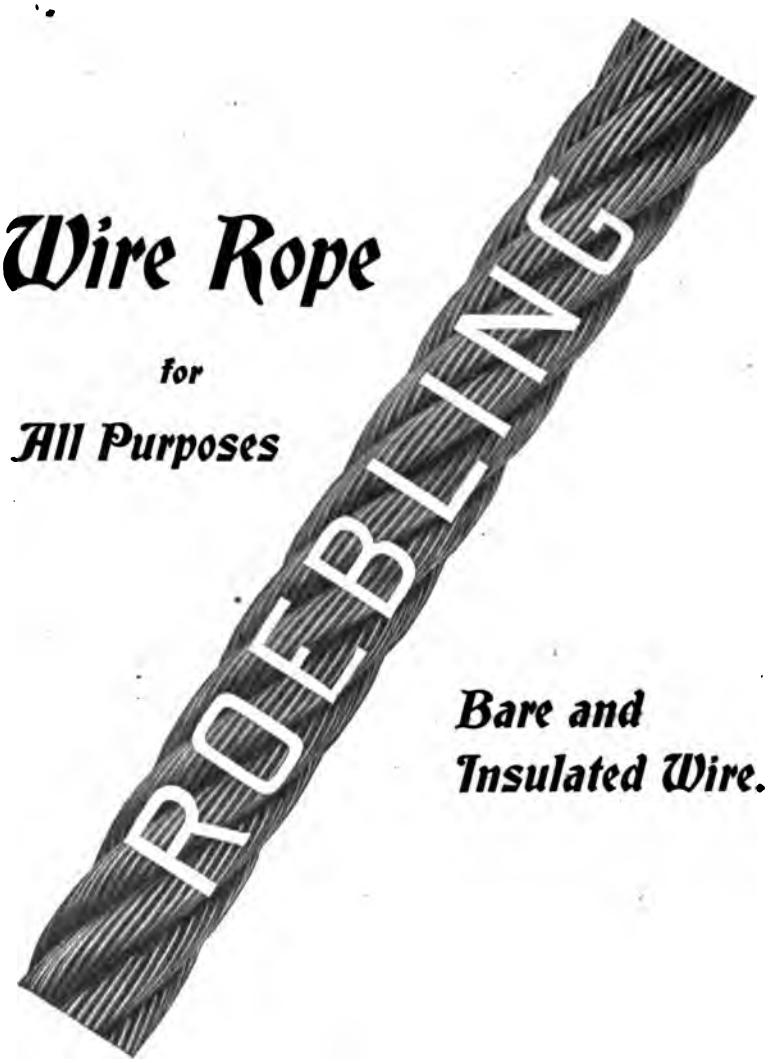

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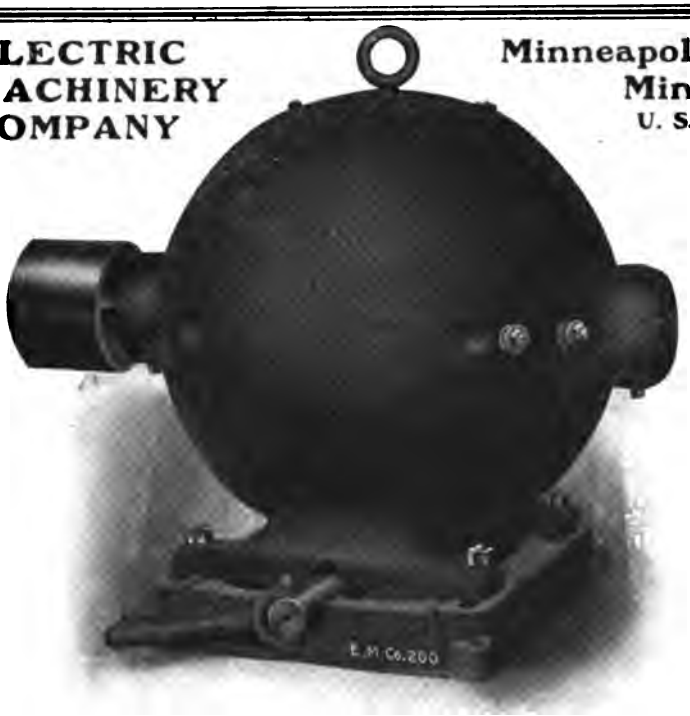

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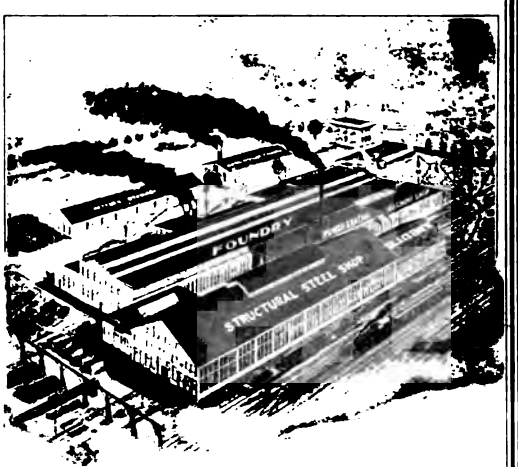

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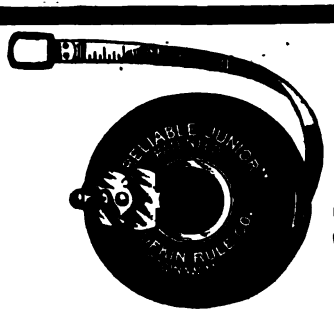

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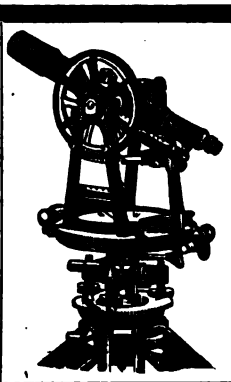

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